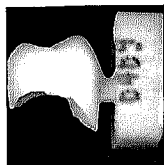


Computer-Aided Direct All-Ceramic Crowns: Preliminary 1-Year Results of a Prospective Clinical Study



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The objective of this study was to investigate the clinical performance of: (1) adhesively placed Cerec crowns with reduced stump preparations, and (2) Cerec endo crowns. The crowns were examined at baseline using modified USPHS criteria in 20 patients with 10 Cerec crowns with reduced stump preparations and 10 Cerec endo crowns. All crowns had been produced chairside with the Cerec 3 CAD/CAM method using the function mode. The crowns were machined from Vita Mk II feldspathic ceramic blocks, polished manually, and placed with dual-curing composite luting agent using a functional adhesive. After 1 year, a follow-up examination of the crowns was conducted; all 20 Cerec crowns were rated with a clinically acceptable A or B rating. Fractures or loss of retention were not observed. The method of producing and placing all-ceramic crowns with reduced stump preparations and endo crowns chairside in one appointment can be implemented successfully in private practice. (Int J Periodontics Restorative Dent 2004;24:446–455.)

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During past years, the vision of producing all-ceramic crowns chairside has turned into a real option to be considered for private practice. A choice of computer-aided design/manufacturing (CAD/CAM) systems is available on the dental market (Celay, Mikrona; Cerec, Sirona; Procera, Nobel Biocare), allowing the machining of crowns and crown copings based on digitally recorded preparation data.

The aim of producing and placing a ceramic restoration chairside in one appointment is best met by the Cerec method.¹ The positive long-term results with Cerec inlays and onlays^{2,3} of feldspathic ceramic using the Cerec 1 method have led to an expansion of the treatment options to include crowns. The Cerec 2 method is the first to allow for the production and placement of crowns⁴; in most cases, a reference impression or waxup is used to aid the design (correlation mode). With Cerec 3,⁵ it became possible to produce crowns in the clinical routine of a private practice, directly at chairside, and to place them within an acceptable period, without the need

Table 1 Distribution of Cerec crowns

Type of restoration	Molars		Premolars		Total
	Maxillary	Mandibular	Maxillary	Mandibular	
Reduced crown preparation	2	3	3	2	10
Endo crown	4	5	1	0	10
Total	6	8	4	2	20

for a preimpression. Furthermore, the results regarding adhesive bonding options of ceramic blocks^{6,7} show that it is possible to deviate from the classic preparation technique; so-called "reduced" preparations or "endo" preparations into the cavity of the tooth can be conducted successfully.⁸ The current study was a 1-year follow-up on the clinical performance of Cerec crowns with reduced stump or endo preparations produced chairside in a private practice environment.

Method and materials

Patients and indications

From the patients of a private practice, 20 (11 women, 9 men) have been recruited so far to participate in the study. The mean age of the patients was 52 years (range 25 to 79 years). All patients needed to have one new crown in a molar or premolar because of insufficient old reconstructions or tooth fractures.

Patients were informed about the treatment options of a conven-

tional porcelain-fused-to-metal crown or a Cerec crown, for which long-term results are still lacking. The main reasons for deciding in favor of the Cerec crown were the possibility of treatment in one appointment as well as avoiding the use of any metal. All patients presented with good oral hygiene and were integrated into the dental hygiene recall scheme of the dental office. In 10 patients, five premolar crowns and five molar crowns with reduced stump preparations were placed. In another 10 patients, endo crowns were seated in one premolar and nine molars that had previously undergone root canal treatment (Table 1).

Clinical procedure

All Cerec crowns were produced with the Cerec 3 unit and with the function mode of the crown software (version 1.20R800). In this procedure, an optical impression of the initial clinical situation is recorded and subsequently superimposed with a second optical impression

taken after preparation. To ensure adequate occlusal forces on the prospective ceramic reconstruction, the occlusion was checked carefully for interferences. Occlusal interferences and lateral forces were removed prior to scanning. This provides the computer with the necessary data to adapt the occlusion of the new crown to the original bite situation.

For optimum drainage—to allow for the creation of the white, matte surface (Vita Cerec Powder, Vita) necessary for taking the optical impression—a rubber dam (Ivory, Heraeus Kulzer) was placed and adapted to the specific conditions of the individual preparation. Preparation was conducted with a 90- μ m diamond bur, and the preparation margins were contoured with 40- μ m diamond finishing burs (Uniprep C&B-Set, Intensiv). Depending on the initial clinical situation, two preparation forms were used. In vital teeth with old restorations or partial fractures, the reduced form was used ($n = 10$); all foreign material was removed, but no buildup was made (Fig 1). In nonvital teeth ($n = 10$), the



Fig 1a Vital premolar with buccal cusp fracture: indication for reduced stump preparation.

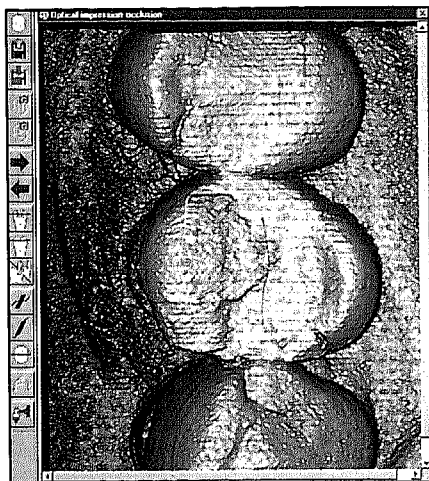


Fig 1b (right) Occlusion is saved in the computer. The missing cusp is replicated closely enough to represent the occlusal situation for the optical impression (Fermit N, Ivoclar Vivadent).

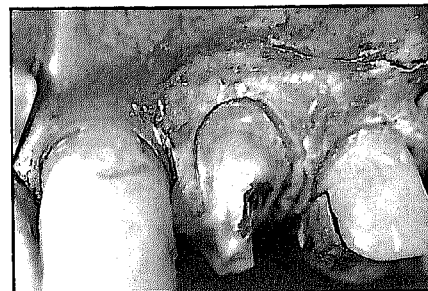


Fig 1c After removing the old amalgam restoration, no buildup is made and the tooth is prepared in a reduced form, ready for the second optical impression.

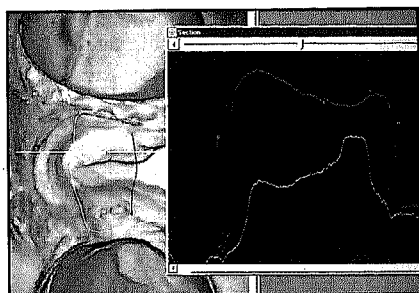


Fig 1d (left) Crown may now be digitally designed using the data of the superimposed occlusion and preparation impressions.

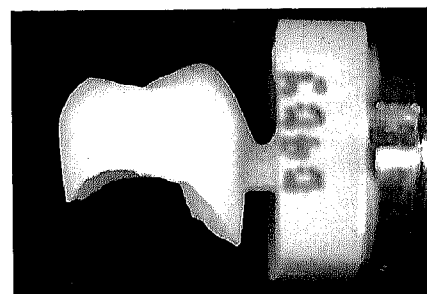


Fig 1e (right) Crown is machined from a feldspathic ceramic block with Cerec grinding unit.

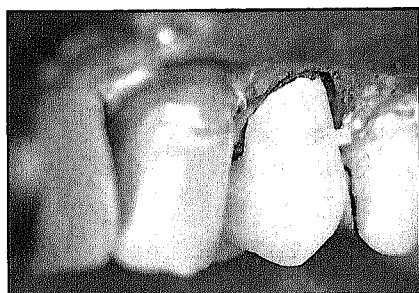


Fig 1f (left) Try-in of raw ceramic block, checking accuracy of fit, anatomic form, and interproximal contacts.

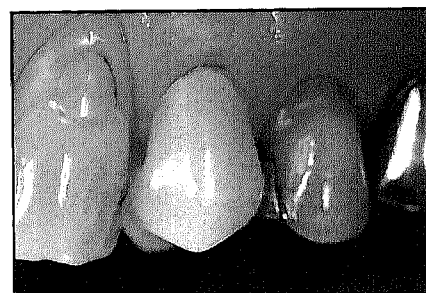


Fig 1g (right) Well-integrated Cerec crown after 14 months in function.

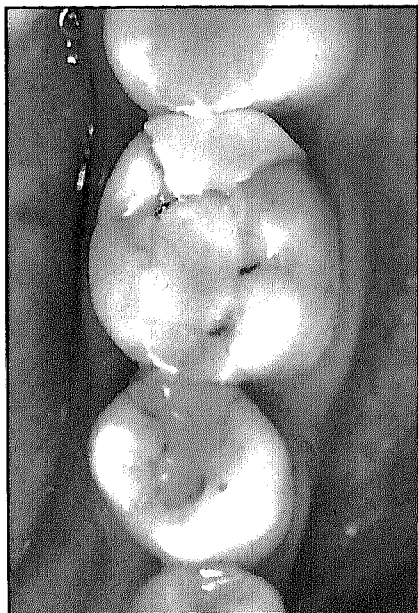


Fig 2a Status after root canal treatment in molar with failing provisional restoration.



Fig 2b Endo crown preparation before taking optical impression.

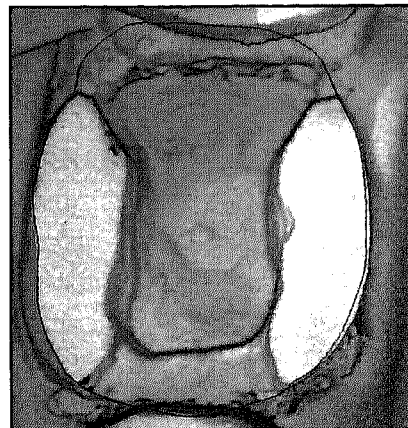


Fig 2c Optical impression of preparation is used as the basis for reconstruction.

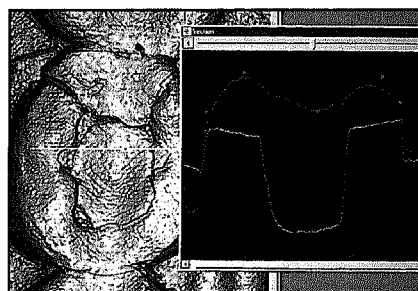
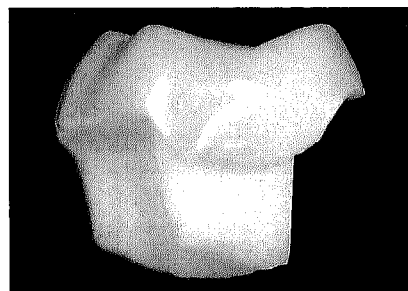


Fig 2d (left) Designing endo crown using saved occlusal impression.

Fig 2e (right) Machined Cerec endo crown is prepolished, and internal surface is acid etched before placement.



clinical crown was completely replaced by the ceramic, and an inlay-shaped post was prepared in the cavity of the tooth (Fig 2). With an epigingival or slightly subgingival (0.5 mm) location of the preparation margin, retraction cord (Ultrapak, Ultradent) was placed.

The crowns were reconstructed on the screen based on the optical impression of the preparation and the initial situation and subsequently machined from a feldspathic ceramic block (Vita Cerec Mk II, Vita) in the Cerec grinding unit. The crown machined in this fashion was tried in and tested for accuracy of fit (Fit

Checker, GC). The interproximal contacts, which can be digitally adjusted in all three dimensions, were checked carefully with waxed dental floss (ACT, Johnson & Johnson). Usually, the contact points were constructed slightly too strong and adapted clinically with a diamond bur. In case of a weak interproximal

contact or questionable fit at try-in, this part of the construction was redone on the reconstruction file saved in the computer and the crown was milled again. The alternative of additional firing (Vitadur Alpha, Vita) to add ceramic for corrections was not chosen because it would have been much more time consuming.

The interdental surfaces were repolished. No color characterization or final firing took place. The internal surface of the crown was etched with 5% hydrofluoric acid (Vita Ceramics Etch, Vita) and silanized (Vitasil, Vita). The enamel remaining on the tooth was etched for 20 seconds with 35% phosphoric acid (Ultra-Etch, Ultradent), and a functional dentin-enamel adhesive (ART Bond, Coltène) was applied to the preparation surfaces. The crowns were placed with a dual composite luting agent (Duo Cement Plus, Coltène) and cured with a halogen curing light (Coltolux 4, Coltène) 5 times for 40 seconds. After removal of the rubber dam, the occlusion was examined again in centric relation and function, and finished with fine 40- and 15- μ m diamond burs (Composhape-Set, Intensiv); excess marginal cement was removed, and the crown was polished with flexible disks (Sof-Lex, 3M), interdental polishing strips (3M), and polishing brushes (Occlubrush, Hawe Dental). The patient chair time needed for each crown ranged from 90 to 120 minutes, depending on the clinical situation.

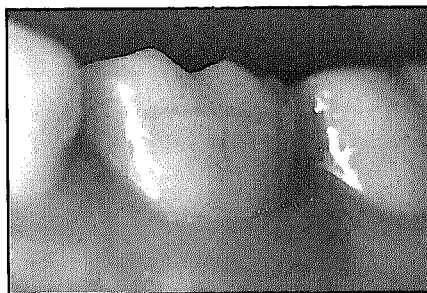
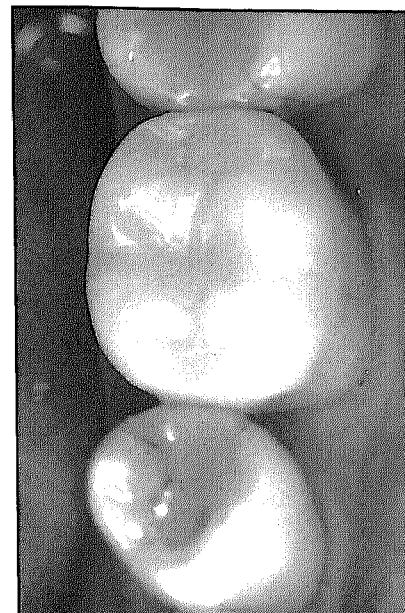


Fig 2f Adhesively placed Cerec endo crown after 15 months in function.

Fig 2g (right) Saved information on position of cusps before preparation allows transfer to correct individual anatomic ceramic reconstruction.



Evaluation

After applying the cement, the data for the modified US Public Health Service (USPHS) criteria⁹ (Table 2) were recorded. In addition, radiographs and clinical photographs were taken. A periodontal examination was conducted for

all reconstructed teeth and their neighboring teeth using probing pocket depth, sulcus bleeding index,¹⁰ and Plaque Index.¹¹ After 1 year, a clinical follow-up examination of the Cerec crowns was conducted visually using a mouth mirror and an explorer (XP23/12, Hu-Friedy) as well as waxed dental

Table 2 Modified USPHS criteria used for classification of crowns

Rating	Criteria
Marginal adaptation*	
A	Crown margin not discernible; probe does not catch; no discoloration visible
B	Probe catches on crown margin but no gap; gap or chipping on probing, with enamel exposed but polishable; slight discoloration visible but polishable
C	Gap or chipping, with dentin or liner exposed; distinct discoloration visible, not polishable; unacceptable
D	Partial fracture, fracture, luxation, or mobile (loose) restoration
Anatomic form†	
A	Correct contour, with tight proximal contact; no wear facets on restoration; no wear facets on opposing teeth
B	Slightly under- or overcontoured; weak proximal contact; small wear facets (< 2-mm diameter) on restoration; and/or same on opposing teeth
C	Distinctly under- or overcontoured; no proximal contact; large wear facets (> 2-mm diameter) on restoration; and/or same on opposing teeth
Surface texture*	
A	Smooth, glazed, or glossy surface
B	Slightly rough or dull surface
C	Deep pores or rough or unevenly distributed pits; cannot be refinished
Color match‡	
A	Restoration hardly detectable; perfect match
B	Minimal mismatch in shade; one shade off (Vita shade guide)
C	Distinct difference in shade; more than one shade off

*Checked using mirror and explorer.

†Checked using mirror, explorer, and waxed dental floss.

‡Checked using mirror.

floss (ACT). The results were again rated based on the modified USPHS criteria (Table 3). In addition, questionnaires were used to obtain information about the patients' subjective satisfaction and potential postoperative discomfort. Sensitivity was assessed using a CO₂ test, and radiographs were taken. The crowns were also documented photographically. Crowns that did not show any clinical alteration and did not require any follow-up treatment were

rated A. Crowns presenting minor defects (eg, moderate overhangs or undercuts, or slight changes in texture and color) that did not have any influence on the clinical result were allocated the rating B. C and D ratings were given to crowns that required repairs or even replacement restorations because of fractures, major defects, or retention loss. Furthermore, crowns presenting sensitivity problems, persisting pain, or secondary caries were rated clinically unacceptable.

Table 3 Modified USPHS rating of restorations

Parameter	Molars (n = 14)		Premolars (n = 6)		Reduced crowns (n = 10)		Endo crowns (n = 10)	
	Baseline	1 y	Baseline	1 y	Baseline	1 y	Baseline	1 y
Marginal adaptation								
A	9	4	5	3	7	6	7	3
B	5	10	1	3	3	4	3	7
C	0	0	0	0	0	0	0	0
D	0	0	0	0	0	0	0	0
Anatomic form								
A	7	7	5	5	6	6	6	6
B	7	7	1	1	4	4	4	4
C	0	0	0	0	0	0	0	0
Surface texture								
A	6	3	5	2	7	3	4	2
B	8	11	1	4	3	7	6	8
C	0	0	0	0	0	0	0	0
Color match								
A	4	4	2	2	3	3	3	3
B	10	10	4	4	7	7	7	7
C	0	0	0	0	0	0	0	0

Results

Ten patients with one crown with reduced stump preparation each and 10 patients with one endo crown each were included in the follow-up examination. Mean functional time was 15 months (12 to 16 months). None of the crowns were allocated a C or D rating after 1 year of service. In particular, fractures or loss of retention were not seen. Of the reconstructions that received a good clinical rating, the number of

crowns that received a B rating for marginal adaptation increased after 1 year from 30% to 55%. For the criterion surface quality, B ratings increased from 45% to 75%. In terms of anatomic shape and color, the number of A ratings (60% and 30%, respectively) and B ratings (40% and 70%, respectively) did not change (Table 3). Caries and endodontic problems were not observed at the follow-up examination. All patients were satisfied with the appearance and chewing comfort of their Cerec

crowns, and no food impaction was reported. There were no complaints about persisting discomfort of any kind after placement of the reconstructions.

Discussion

Since the Cerec 3 method was introduced only in 2000, long-term studies on the clinical performance of these reconstructions are still lacking. The short time span since the

introduction of this technology for practice also limited the number of cases available for evaluation. The aim of presenting early results was to communicate whether the Cerec 3 method for production and placement of all-ceramic crowns—chairside, in one appointment, and without any physical impression—can be successfully implemented in private practice.

Earlier experience with crowns produced using Cerec 2 well documented the technical prerequisites for achieving good results with regard to accuracy of fit,¹² fracture resistance,¹³ and adhesive bonding.¹⁴ In particular, with reduced stump preparations or endo crowns, fracture resistance significantly increases with greater ceramic thickness.⁸ This may contribute to minimizing the fracture risk of all-ceramic Cerec 3 crowns with reduced stump preparations and endo crowns. In comparable all-ceramic crowns, fractures are the most frequent reason for failure. IPS Empress complete crowns (Ivoclar Vivadent) show a fracture rate of 5% after 2 years,¹⁵ and one private practice demonstrated a fracture rate of 6% up to 4 years.¹⁶ Dicor crowns (Dentsply) have a considerably higher fracture rate of 14%¹⁷ and 16%.¹⁸

The reduced stump preparation exhibits less preparation surface than the classic conical crown stump. Thus, macromechanical retention is reduced or nonexistent. The question is whether sufficient microretention can be provided by the adhesive bond of the crown. In the case of endo crowns, the effects of

force transmission between the rigid ceramic of endo crowns and the remaining hard tissue are unclear; long-term experience will have to show whether this type of construction holds true over time. However, the building up of crown stumps using root posts has been critically reviewed repeatedly.^{19–21}

Keeping this in mind, the computer-generated endo crown seems to offer a valid alternative for the reconstruction of nonvital teeth.²² The preliminary results of the present study after 1 year show good clinical performance of Cerec 3 crowns with reduced stump preparations and endo crowns. The chairside concept to produce and place all-ceramic crowns with reduced stump preparations and endo crowns in one appointment can be successfully implemented in private practice and shows high clinician and patient benefits.

Conclusions

1. Cerec crowns with reduced stump preparations and Cerec endo crowns can be easily designed and custom machined chairside with anatomically correct proportions, ready to be adhesively placed during a single appointment.
2. Crowns with reduced stump preparations and endo crowns machined from Vita Mk II feldspathic ceramic blocks did not show any fractures after 1 year.
3. Adhesive bonding of all-ceramic Cerec crowns with reduced stump preparations as well as endo crowns using a functional dentin-enamel adhesive and a dual-curing resin-based composite luting agent did not show any loss of retention or root fractures after 1 year.

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