

The occlusal precision of laboratory *versus* CAD/CAM processed all-ceramic crowns

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ABSTRACT: Purpose: The null hypothesis was tested: There is no difference between two all-ceramic crown systems, the Cerec method (CHAIR) and the IPS Empress method (LAB), with respect to occlusal precision and time expenditure for the dentist. **Methods:** 20 casts representing clinical situations were mounted in semi-adjustable articulators to serve as simulation models. The left lower first molars were prepared to receive feldspathic ceramic crowns. The minimum number of three (Min3) occlusal contacts and their desired location was defined on each crown before preparation. Two crowns were produced on each die: (CHAIR) was applied in order to simulate a chair-side treatment and [LAB] was applied to simulate the laboratory/clinical mode of production. Additionally the time required to perform the occlusal adjustment was measured. For occlusal analysis, the (Min3) were divided by the contacts that were “actually achieved” (ACT). Mean quotients for (LAB) and (CHAIR) were calculated ($n = 20$ each). The Wilcoxon signed rank test at $P \leq 0.05$ was applied to determine statistical significance. **Results:** The mean quotients MEAN QU (Min3)/(ACT) of 0.87 for (CHAIR) and 0.94 for (LAB) and the time expenditure for simulating intraoral occlusal adjustment of 3.44 minutes for (CHAIR) and 3.79 minutes for (LAB) did not differ significantly. (*Am J Dent* 2010;23:53-56).

CLINICAL SIGNIFICANCE: The clinical simulation showed that it was possible to achieve satisfactory occlusal precision either by the use of the conventional laboratory (LAB) and the CAD/CAM (CHAIR) method within similar time expenditure.

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Introduction

Occlusion and occlusal interface are important subjects in daily dental practice.¹⁻³ When performing single tooth restorations in patients, it is important that the restoration contribute to harmonious function so that normal function is achieved and non-physiologic occlusion is avoided.⁴⁻⁶ Byron's considerations on “optimal occlusion” from 1969 and 1973 are still the basis for the description of a functional occlusal rehabilitation.⁷⁻⁹ Only a few clinical investigations have studied the number of occlusal contacts in full dentition and have reported between 10.6 and 55 contacts.⁹⁻¹² Two clinical studies^{10,11} investigating the number of contacts in the full dentition revealed three contacts on molars under intense occlusion. For the clinician, it is important to achieve a restoration that is in occlusal harmony both functionally and morphologically and that can be finished intra-orally in an acceptable amount of time. Therefore, the aim of this study was to compare a laboratory-processed crown system, the IPS Empress (LAB) method, with a chair-side based system, the Cerec 3D method (CHAIR), with respect to the precision of occlusal contact, morphology, and time expenditure.

Materials and Methods

Twenty pairs of maxillary and mandibular casts (stone gypsum; Esthetic Rock^a) of full dentitions with canine guidance in dynamic occlusion and representing clinically stable interocclusal relationships were mounted in an articulator to serve as simulating models. The mandibular left first molars made of acrylic resin (Picopoly^b) was prepared to receive an all ceramic feldspathic crown. Prior to the preparation, the location of a minimum of three static contacts on the future crown

restoration was determined and noted in an occlusal card by the operator who did the (CHAIR) crowns and by the dental technician who produced the (LAB) crowns according to the recommendation of Byron.^{7,8} The simulation casts #1-5 and #11-15 first served as “patient” models for the (LAB) method. After completely having finished the production and analyzing procedure for the (LAB) crowns the (CHAIR) crowns were directly done on these casts. On the simulation casts #6-10 and #16-20 the process was reversed.

Producing the IPS Empress^c crowns - Due to the fact that IPS Empress technique (LAB) is an indirect (laboratory based) technique, impressions of the upper and lower simulation cast were made by applying the double mix technique (Panasil^d binetics putty soft and Panasil contact plus). The casts made of stone gypsum were mounted arbitrarily in a semi-adjustable articulator, and the (LAB) method was applied according to the manufacturer's guidelines to produce leucite reinforced all-ceramic crowns from wax patterns by one single dental technician.

Producing the Cerec^e crowns - The (CHAIR) method was directly applied onto the prepared tooth (software version 2.8, “Articulation” mode). After powdering the surfaces (Scan Spray^f) and Vita Cerec Powder,^e one dentist took three single optical impressions with the Cerec camera in order to capture the preparation, the mesial and distal adjacent teeth for a virtual three-dimensional (3D) model. Then a static bite registration was made by covering the occlusal plateau of the preparation with a silicone material (Futar D Scan^d) by closing the articulator. The bite registration and the adjacent powdered structures were photographed as well. The information about the static occlusion (virtual occlusion model) was superimposed

on the die. Additionally a dynamic bite registration was produced by covering the preparation with silicone and doing latero- and protrusion in the articulator (Fig. 1). After the material set, this functional guided pathway registration was captured and could now provide information about the dynamic paths of the antagonist teeth. The virtual design was done by modifying a basic morphology that was suggested by the software. The contact points were created according to the occlusal card. The contact points were designed in a way that they penetrated the virtual bite registration up to 50 μm , which meant that they were displayed by the software option “inter-occlusal clearance” colored in green on the designed crown (Figs. 2, 3). The restorations were then milled from a ceramic Vita MK II blank.^e

Proximal, internal, and marginal fit - The following clinical simulations were conducted by the same dentist who operated the Cerec system. Similar processes were used for checking the proximal, internal, and marginal fit of the (CHAIR) and the (LAB) crowns. Whereas the (LAB) restorations were finished in the laboratory, the (CHAIR) crowns had to be tried-in in the simulation cast immediately after milling. The (LAB) crowns were now immediately analyzed regarding their occlusal precision. Prior to occlusal analysis, the (CHAIR) crowns were polished under water cooling with polishing disks (Sof-Lex,^g blue color code) and glazed (Vita Shading Pastes, Glaze). At this point the (LAB) and (CHAIR) crowns had reached an identical production status.

Simulation of grinding procedure - The dentist inserted the respective crowns and checked the contacts of the adjacent teeth with their antagonists using black articulating foil^h (8 μm). The weight of the upper part of the articulator served as load to imitate the “bite force”. If the foil was not captured by the adjacent teeth the height of the restoration was adjusted. From that moment on the time measurement began. If grinding was not necessary a “0” was noted. If it was necessary, egg-shaped fine grid diamonds were used first, followed by disks (Sof-Lex disks, progressing from a dark blue color to light blue code) in order to get a polished surface. Finally the adjacent teeth were checked for identical contacts with and without the inserted crown. After the polishing procedure was finished the time measurement in minutes and seconds was stopped.

Analysis of the occlusal contacts - The analysis of the occlusal contacts was done by a different operator who was not involved in the production process. The incisal tip was raised at least 0.5 cm. First it was checked with two articulating foils^h (black and red, 8 μm) if the contacts on the non-treated teeth were identical, with and without the inserted crowns. All 40 crowns had no premature contacts. In order to analyze the contact point situations for the (LAB) and the (CHAIR) crowns, quotients comprising the following parameters were calculated:

1. (Min3) = The minimum number of three defined contacts before preparation;
2. (DES) = Maximum of possible desired contacts defined before preparation = (Min3) + X;
3. (ACT) = actual number of contacts that corresponded to the previously defined positions comprising (Min3) and (DES).

Then the following mean quotients were calculated with $n = 20$ for both (LAB) and (CHAIR) restorations:

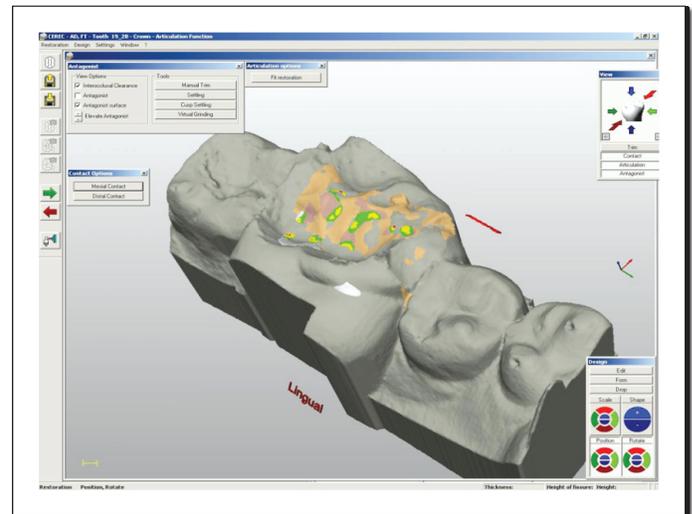


Fig. 1. (CHAIR) method: Both the functionally guided pathway (FGP) registration (grey) and the static registration (brown) are virtually superimposed on the preparation model. The green, yellow, and red markings indicate the areas of the designed crown that penetrate the registration.

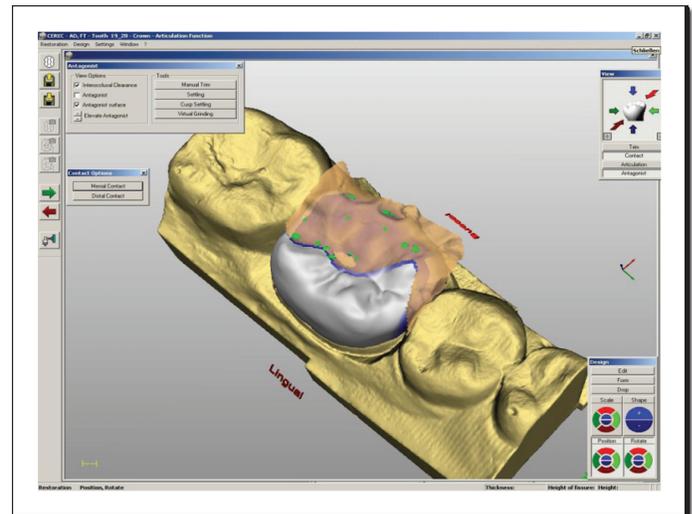


Fig. 2. (CHAIR) method: After virtually grinding off the premature contacts in dynamic occlusion, the FGP surface is hidden. The surface of the preparation model and the designed crown are displayed in relation to the static bite registration. The areas in green represent desired contacts.

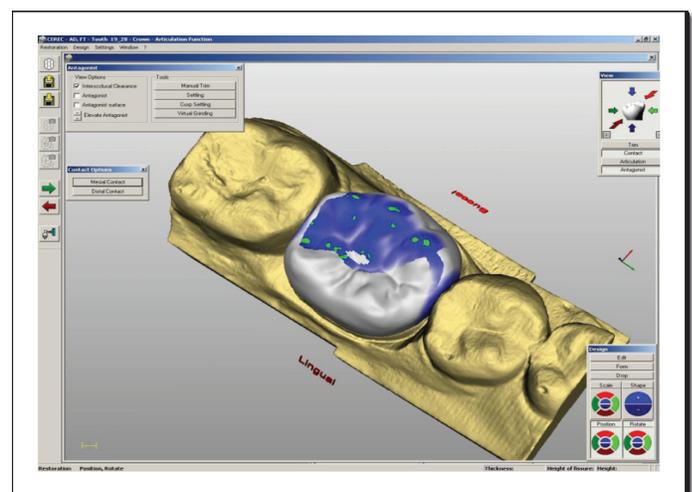


Fig. 3. (CHAIR) method: Designed crown ready for milling.

Table 1. The mean quotients for (Min3)/(ACT) and (DES)/(ACT) for the (Chair) and (Lab) restorations (n = 20 each) are shown. Additionally, the 95% confidence intervals (lower and upper bounds), the median values of the quotients, and the minimum and maximum quotients are displayed.

	(Min3)/(ACT) _(CHAIR)	(Min3)/(ACT) _(LAB)	(DES)/(ACT) _(CHAIR)	(DES)/(ACT) _(LAB)
Mean	0.87	0.94	1.90	2.08
95% confidence interval				
Upper bound	0.59	0.79	1.25	1.68
Lower bound	1.15	1.10	2.54	2.48
Median	0.68	1.00	1.37	2.00
Minimum	0.33	0.43	1	1
Maximum	3.00	1.50	7	4

1. The mean quotient (Min3)/(ACT) for (LAB) [indicated as (Min3)/(ACT)_(LAB)] and the mean quotient (Min3)/([ACT) for (CHAIR) [indicated as (Min3)/(ACT)_(CHAIR)] was 1 if the postulate for the minimum number of contacts was fulfilled exactly. A mean quotient less than 1 indicated that more than (Min3) reasonable contacts were achieved. A mean quotient greater than 1 indicated that (Min3) was not fulfilled.
2. If the mean quotient (DES)/(ACT)_{(LAB)/(CHAIR)} was greater than 1, the maximum desired number of contacts was not achieved in every phantom situation. Of course, a value less than 1 was not possible due to the definition of (ACT).

In order to assess the entire morphology of the occlusal surface, all (LAB) and (CHAIR) samples were assessed by a dental technician master who was the chairman of the Examination Board for Dental Technicians of the Chamber of Skilled Trades. The restorations were assessed according to the following criteria:

1. Main fissure line: shape, oro-vestibular location;
2. Shape of the decline of the cusps: location and shape;
3. Marginal ridge: location and shape, transition to the occlusal surface;
4. Distance from the main fissure line to the cusp tips;
5. Extension of the occlusal surface: under/over extension in mesio-distal and oro-vestibular direction.

The examiner rated the single items with “++”, “+”, or “-”. Finally, he was asked to decide whether the restoration could be inserted from a morphological point of view or not. A rating of “1” indicated that the morphology was perfect; “2” = needs slight improvements, insertion still acceptable; “3” = immediate insertion not recommended because major improvements were needed.

The statistical analyses were done using SPSS, version 11.0.¹ The differences in the values of (LAB) and (CHAIR) were tested for significance using the Wilcoxon signed ranks test at P ≤ 0.05.

Results

In the (CHAIR) group, six crowns out of 20 did not need any occlusal adjustment; in the (LAB) group, three restorations did not require any corrections. The other crowns needed adjustment due to the fact they showed premature contacts. Table 1 shows the analysis of contact points of the fabricated crowns.

For all (CHAIR) and all (LAB) crowns it was possible to create at least one stable contact that corresponded to one of those contacts (DES) that were defined before the simulation of the treatment. For (CHAIR), the lowest number of contacts was 1 (one time) and for (LAB), 2 (four times).

Table 2. Morphological assessments of the (CHAIR) and (LAB) productions.

Rating	(CHAIR)		(LAB)	
	Assessments per rating Number	%	Assessments per rating Number	%
1	7	35	5	25
2	11	55	11	55
3	2	10	4	20

The mean quotient of (Min3)/(ACT)_(CHAIR) of 0.87 (range: 0.33–3.00) and the mean quotient of (Min3)/(ACT)_(LAB) of 0.94 (range: 0.43–1.50), did not differ significantly.

The mean quotient of (DES)/(ACT) for (CHAIR) was 1.9 (range: 1.0–7.0) and for (LAB) it was 2.08 (range: 1.0–4.0) (Table 1).

Time expenditure - The mean time expenditure for grinding and polishing in order to improve the contacts was 3.44 minutes (SD ± 3.27) for (CHAIR) and 3.79 minutes (SD ± 3.89) for (LAB).

Morphology - The dental technician master rated 18 (CHAIR) and 16 (LAB) crowns at 2 or better (Table 2). The results did not differ significantly at P ≤ 0.05.

Discussion

This study evaluated the practicability of two different systems with respect to their ability to create a feasible occlusal morphology in a clinical simulation trial. Furthermore, occlusal analysis in the oral cavity sometimes is ambiguous.¹³⁻¹⁵ If only one definitive restoration was produced per patient by randomly selecting the production system, the number of patients would have to have been increased substantially because the conditions of linked spot checks would no longer be fulfilled. The advantage of applying a rigid model comprising the articulator and casts was that, unlike under natural conditions, inaccuracies are not compensated by the resiliency of oral tissues. One experienced operator did the occlusal adjustment of all crowns. It seemed to be the lowest bias compared to using two different operators or one inexperienced operator doing the adjustment for each system separately. In the first case the abilities of two different operators would have been measured, in the latter case the learning curve of one operator would have been tested. The results revealed that occlusal adjustment was necessary more frequently for the (LAB) crowns, but the variation of time was in a narrower range.

The minimum number of occlusal contacts is still under discussion. The Wiskott & Belser¹⁶ concept asks for at least one contact point per tooth to preserve occlusal stability. In this

study, every restoration created by the (LAB) and the (CHAIR) systems met this requirement. Other authors^{10,11} have investigated an average of three contact points on molars in clinical investigations. Therefore, a minimum of three contacts per tooth was regarded as satisfactory. The postulate was fulfilled on average. Four (LAB) restorations gained only two contact points, for (CHAIR), only two contacts were gained in two instances, and only one contact was gained on one occasion.

Neither the (LAB) nor the (CHAIR) method reached the requested maximum number of occlusal points (DES) in every case; the quotients (DES)/(ACT) were much greater than 1 for both (LAB) and (CHAIR). However, the mean quotients did not differ significantly from one another.

With regard to overall morphological quality, two (CHAIR)-generated crowns and four (LAB)-generated crowns were rated "3" by the dental technician master, possibly due to the rule that every crown had to be completed.

Besides function and morphology, it is also important to achieve these results in an acceptable time. A mean value of less than 4 minutes was found for both systems.

Finally it could be stated that mandibular left first molar crowns manufactured with a chair-side CAD/CAM method did not differ from those manufactured with a well-established laboratory method with respect to occlusal precision.

- a. Dentona, Dortmund, Germany.
- b. Picodent, Wipperfurth, Germany.
- c. Ivoclar Vivadent, Schaan, Liechtenstein.
- d. Kettenbach, Eschenburg, Germany.
- e. Vita Zahnfabrik, Bad Säckingen, Germany.
- f. Dentaco, Hamburg, Germany.
- g. 3M ESPE, Seefeld, Germany.
- h. Dr. Jean Bausch, Cologne, Germany.
- i. SPSS, Chapel Hill, NC, USA.

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