Retrievability of Implant-Supported Crowns When Using Three Different Cements: A Controlled Clinical Trial

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Purpose: The purpose of this study was to analyze the removal of implant-supported crowns retained by three different cements using an air-accelerated crown remover and to evaluate the patients' response to the procedure. ***Materials and Methods:*** This controlled clinical trial was conducted with 21 patients (10 women, 11 men; mean age: 51 ± 10.2 years) who had received a total of 74 implants (all placed in the posterior zone of the mandible). Four months after implant surgery, the crowns were cemented on standard titanium abutments of different heights. Three different cements (two temporary: Harvard TEMP and Improv; and one definitive: Durelon) were used and randomly assigned to the patients. Eight months later, one blinded investigator removed all crowns. The number of activations of the instrument (CORONAflex, KaVo) required for crown removal was recorded. The patients completed a questionnaire retrospectively to determine the impact of the procedure and to gauge their subjective perception. A linear regression model and descriptive statistics were used for data analysis. ***Results:*** All crowns could be retrieved without any technical complications or damage. Both abutment height ($P = .019$) and cement type ($P = .004$) had a significant effect on the number of activations, but the type of cement was more important. An increased total number of activations had no or only a weak correlation to the patients' perception of concussion, noise, pain, and unwillingness to use the device. ***Conclusions:*** Cemented implant crowns can be removed, and the application of an air-accelerated device is a practicable method. A type of cement with appropriate retention force has to be selected. The impact on the patients' subjective perception should be taken into account. *Int J Prosthodont 2015;28:22–29. doi: 10.11607/ijp.4119*

Single crowns supported by implants are a well-documented and predictable treatment modality.[1–3] Advantages of cement retention over screw retention have been addressed in several studies.[4–6] Moreover, cementation may reduce chairside time and is popular among clinicians.[3] Inaccuracy of standard fabrication of fixed porcelain-fused-to-metal prostheses cannot be completely avoided. Inaccuracies, even so small as to be undetectable by dentists, may lead to strain and stress in the implant surrounding bone and the implant superstructure itself, particularly when they are screw-retained and the screws are tightened.[7–9] Therefore, the authors concluded that passive fit cannot be achieved by conventional fabrication techniques and cementation may compensate for accuracy. The fabrication of crowns for cement-retention on implant abutments is a simpler technology and comparable to the technique of fabricating crowns for teeth.

A recent systematic review confirmed favorable treatment outcomes with single crowns supported by implants, but showed that minor technical complications are rather frequent.[10] From this point of view, retrievability may be important. Retrievability of implant-supported crowns and prostheses allows for

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the clinical inspection of the single standing implant. This is advantageous for long-term clinical monitoring and recording of peri-implant parameters. Minor repair and corrections of the superstructure can be carried out.[11] Thus, for clinical use, a luting agent should be available with sufficient strength to maintain the crown in place when subjected to occlusal load and masticatory function. Otherwise, the bonding strength of the cement should enable the dentist to dismount the superstructure with special instruments. If the adhesive strength of permanent cement is high, the risk of damaging the superstructure by the removal procedure must be underscored. Several authors describe a good predictability of retrieval in cases when the superstructures were fixed on implant abutments using provisional or semi-permanent luting agents or definitive cements with limited retention forces on implant abutments.[4,6]

Various tools and procedures are described and utilized for removal of cemented single crowns. Conventional methods involve the application of physical force, for example, with rubber-coated pliers or a crown chisel. This may be effective but often destroys a critical part of the crown, albeit in small amounts.[11] Various mechanical tools have been developed for gentle application of force, such as resin-based removers,[12] retrieval screws,[13] rotating lever systems,[14] or instruments that produce a kinetic impulse.[15] The use of electrical aids such as ultrasonic devices is gaining popularity, as well.

This study is part of a research project on implant-supported single crowns in the posterior zone of the mandible. Results on crestal bone alterations have already been published elsewhere.[16] This controlled clinical trial investigated the effectiveness of a kinetic impulse instrument for removing single crowns supported by implants that were seated on prefabricated standard abutments and compared three types of cements. In addition, the patients' attitude toward this technique and their responses to the application of this instrument were evaluated.

Materials and Methods

Patients and Implants

This controlled clinical trial was conducted with 21 patients (10 women, 11 men; mean age: 51 ± 10.2 years) recruited at the Dental Clinic Bochum/University of Witten-Herdecke, Germany. The inclusion criteria were good general health; absence of infectious diseases, diabetes, or osteopathy; no active periodontitis; no drugs influencing the bone metabolism; no pregnancy or nursing; no dental phobia. All patients had unilateral or bilateral edentulous spaces in the posterior mandible, which allowed the placement of at least two implants per patient to support single crowns. A standard surgical procedure had to be performed, ie, without grafting and guided bone regeneration. The patients were thoroughly informed about the possible risks and benefits and all signed a written informed consent form. The study was performed in compliance with Good Clinical Practice and the Declaration of Helsinki, last revised in Edinburgh 2000; the study protocol was reviewed and approved by the Clinical Trials Committee of the University of Witten-Herdecke.

The implant system used in the present study was the SICace implant (SIC-Invent). All implants used had a diameter of 4 mm and a length of 9.5 mm. Twenty-one patients received a total of 74 single implants in the posterior zone of the mandible. The implants were inserted within 1 week at the Dental Clinic Bochum and the University of Witten-Herdecke by one surgeon. The implants were submerged and not loaded during a 3-month healing phase. Thereafter, the implants were exposed and 2 weeks later impressions were taken for fabrication of the definitive crowns. A preliminary try-in session served for intraoral assessment of the frameworks fitting on the prefabricated titanium abutments and for final occlusal registration. One dentist performed the prosthetic treatment, and the crowns were delivered 4 weeks after reentry surgery.

Crowns and Cement Type

Conical standard abutments were used for cementation of the crowns. This standard abutment has a parallel wall in the basal part. A vertical space of 8.5 mm between the peri-implant marginal mucosa and the antagonistic tooth was required to use the standard 6-mm abutment. Therefore, if the space measured was less than the requisite 8.5 mm, the height of the abutment was adjusted according to the interocclusal space available. This meant that the standard abutment was shortened by 1 to 4 mm. Detailed records on the final abutment height were kept by the technician. The surface of the abutment was machined and not modified by the dental technician. One dental technician fabricated the crowns with a cobalt-chromium-tungsten-molybdenum (Co-Cr-W-Mo) alloy (Combibond BST Triumph, Feguramed) using the cast technique (investment material: GC Stellavest, GC). All crowns had a full ceramic veneering with feldspathic porcelain. The inner surface of all crowns was sandblasted in the laboratory.[17] Four months after implant surgery, the SICace titanium abutments were tightened to 25 Ncm on the implants, and the crowns were carefully

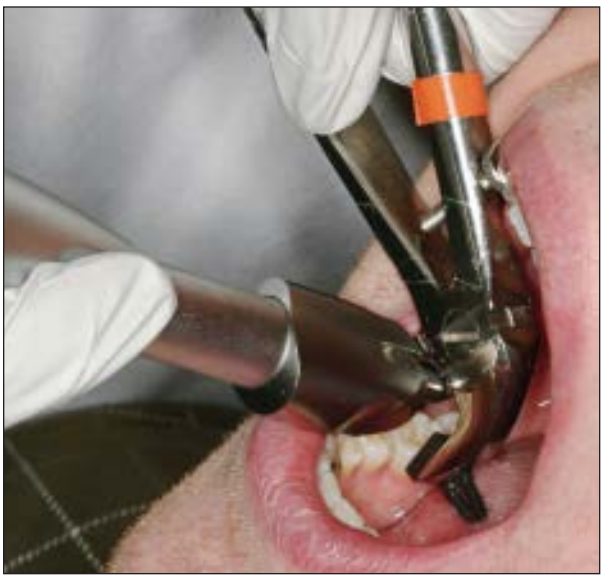

Fig 1 CORONAflex activation in the mouth.

cemented on the abutments in each patient's mouth. For cementation, three different cement types were used: a temporary zinc-oxide (ZnO) cement with limited retention force (HT = Harvard TEMP, Harvard); a temporary cement with an increased retention force (IMP = IMPROV, Alvelogro); and a definitive cement with limited retention force on titanium surfaces (DUR = Durelon, 3M ESPE). Patients were randomly allocated into three cement groups using computer-generated list numbers. All implant crowns of a single patient were retained by the same type of cement. The patient was blinded to the assigned cement. Follow-up appointments were scheduled at 8, 12, and 24 months after implant insertion for assessment of biologic and technical problems and radiographic monitoring of the implants. During the follow-up sessions, the oral hygiene of the test participants was emphasized and oral hygiene instructions given. If necessary, professional plaque control and cleaning procedures were performed.

Crown Removal

Twelve months after implant surgery (8 months after crown delivery), all implant crowns were removed from the abutments by means of an air-accelerated kinetic impulse instrument, ie, the CORONAflex 2005 device (KaVo) and a forceps with rubber-coated tips (Schwert no. 4940-22, A. Schweickhardt). This system has been on the market for more than 10 years. The CORONAflex instrument is plugged into the head of the turbine housing of the dental unit and generates a high kinetic impact upon activation. The instrument consists of a piston that is accelerated along the shaft into the tip of the remover by means of compressed air. The resulting short impact pulse acts on the structure of the interface (cement/metal) and destroys it abruptly, thus eliminating the adhesion. This impulse is specified by the manufacturer with 500 N per ms.

The forceps tips were buccally and lingually placed onto the implant crown. The tip of the remover was placed beneath the forceps joint and activated after slight preloading. It was aimed to set the preload at a level to create enough impact to the rubber tips of the forceps for the removal procedure. One laboratory study applied preloads of 50 and 400 cN.[17] It was also aimed to avoid any tilting of the forceps in order to realize a vertical displacement movement. Figure 1 shows the clinical application of the CORONAflex device and the Schwert forceps. The number of activations was counted and recorded in the study-report form. Activation was stopped when the crown became loose and could be removed by hand. Within a time lag of 2 days, one blinded dentist who had not been involved in the treatment of the patients removed all crowns. After removal, the crowns and the abutments were cleaned with 70% alcohol and then dried with gentle air spray. Afterwards, all crowns were definitively mounted with DUR.

The average and total number of activations per crown was compared among the cement groups. The total number of activations per patient also was calculated.

Questionnaire and 2-Year Follow-up

In the course of the study, all patients were recalled for assessment of the crowns 1 year after the removal test, ie, 2 years after implant placement. All patients were asked to complete a questionnaire, which consisted of 6 questions. These were graded on an 11-point Likert-type scale related to the psychologic impact of the application of the CORONAflex instrument. The questions focused on the patients' subjective perceptions and experiences with the procedure: sensation of concussion, noise, pain, and dental anxiety during and after the crown removal. Items 1, 2, and 3 ranged from 0 (not unpleasant) to 10 (highly unpleasant); items 5 and 6 went from 0 (no anxiety) to 10 (very high anxiety); and for item 4, a 0 meant that the patient would be "willing" to repeat the removal test, and 10 meant he or she would "not consent" to it at any time. The questionnaire is shown in Table 1.

During this recall session, standardized radiographs were taken again and the 2-year crestal bone level changes were measured in relation to the post-surgical radiographs. Mean and median values were calculated and the data were pooled for mesial and distal sites. In addition, technical complications of

the crowns during the entire observation period were registered eg, chipping of the veneering material, crown loosening or complete decementation, abutment loosening underneath the crown.

Statistical Analysis

Prior to the start of the clinical study, sample-size calculations were done using G*Power 3 for matched pairs.[18] In a preliminary in vitro study, the authors had measured activation of the CORONAflex (ACf) instrument at 15.57 ± 4.6 for IMP and 3.5 ± 4.5 for HT of crowns on standard titanium abutments of various heights. Based on these data, it seemed possible to detect a difference between the cement types with 95% power and five patients per group (two-tailed test for differences, 5% level of significance). To compensate for possible dropouts in the present clinical trial with three different cement types, the sample size was adjusted to 21 patients. The primary endpoint of the study was to gauge the effectiveness of the crown removal procedure while comparing three different types of cement. The outcome measure was the number of ACfs per crown and per patient. The global test of dependence of ACf on abutment height and cement type was done using a linear regression model in which logarithms were used to describe the values of ACf. The descriptive statistics and Spearman rank correlation coefficients were used for data analysis. The classification of coefficients was as follows: $0.0 \geq |r| < 0.3$ no to very weak correlation, $0.3 \geq |r| < 0.5$ weak correlation, $0.5 \geq |r| < 0.7$ moderate correlation, $0.7 \leq |r| < 1.0$ strong correlation. The correlation coefficient can range from +1 to −1 (negative coefficient meant a reversed correlation). The influence of the patients' sex on single items of the questionnaire was tested pairwise with the Wilcoxon rank sum test and chi-square test. SAS version 9.2 software (SAS Institute) was used for statistical analysis.

Results

All 21 patients with 74 single crowns were available for removal testing. No implants were lost, and no spontaneous loosening of any crowns from an abutment had occurred during the observed time period. All crowns could be removed and none were destroyed or damaged by the procedure.

The random allocation was as follows: 6 patients had a total of 20 crowns cemented with HT, 6 patients had a total of 19 crowns cemented with DUR, and 9 patients had a total of 35 crowns cemented with IMP. Twenty-eight abutments maintained their original height, whereas 46 were shortened. The overall abutment height ranged from 2.00 to 6.00 mm. No statistically significant difference regarding abutment height among cement groups was found (Kruskal-Wallis test, $P = .3$). The number of ACfs per crown resulted in a range from 3 to 38; however, only 6 crowns were subjected to 20 or more activations. Since the patients had 2 to 5 (one patient, 7) crowns, the ACf per patient resulted in a median value of 14, and 4 patients had a total ACf more than 40. The mean ACf per patients was 22.86. The standard error was 4.99. Table 2 provides a summary of all values.

The abutment height and cement type had a statistically significant effect on ACf: $P = .019268$ and $P = .003885$, respectively (Fig 2). The smaller the abutment height, the lower the ACf value. However, the impact of the cement type was more relevant, with statistically significantly lower ACf values for HT as compared to DUR or IMP: $P = .03$ and $P = .001$, respectively. No difference was found between DUR and IMP.

The patients' retrospective perceptions of having their crowns removed with an air-accelerated crown remover is represented by the questionnaire. The ratings of all patients are shown in Fig 3. The ratings for concussion (item 1) were slightly higher (unpleasant) than for noise and pain (items 2 and

Table 1 Patient Questionnaire*

1. Was the feeling of concussion during crown removal unpleasant?
2. Was the noise during crown removal unpleasant?
3. Was crown removal painful?
4. Would you consent to remove the crowns again?
5. How do you judge your dental anxiety in general?
6. Did your dental anxiety change upon crown removal?

*Scores: 0 to 10, maximum 60 points per patient.

Table 2 Type of Cement, Abutment Height, and Number of Activations

	DUR	HT	IMP	Total
No.				
Patients	6	6	9	21
Crowns	19	20	35	74
Abutment height (mm)				
Range	2.0–5.5	2.5–6.0	2.0–6.0	2.0–6.0
Mean	4.25 ± 0.99	5.63 ± 0.8	5.27 ± 1.05	5.1 ± 1.10
Median	4.4	5.2	5.5	5.45
SE	0.23	0.18	0.18	0.13
No. of activations/crown				
Range	1–20	1–20	1–38	1–38
Median	3	2	3	3
Mean	4.3 ± 4.32	3.7 ± 4.67	9.37 ± 11.13	6.54 ± 8.68
SE	0.99	1.04	1.88	1.01

DUR = Durelon (definitive); HT = Harvard TEMP (temporary); IMP = IMPROV (temporary); SE = standard error.

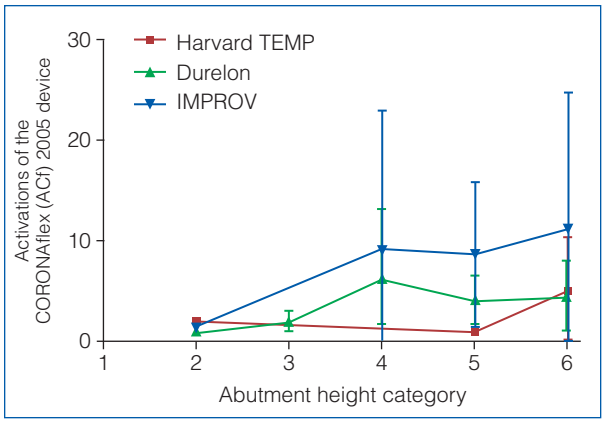

Fig 2 ACf for three cements in relation to abutment height. Abutment height categories: 2 = 2.0–2.4 mm; 3 = 2.5–3.4 mm; 4 = 3.5–4.4 mm; 5 = 4.5–5.4 mm; 6 = 5.5–6.0 mm.

Table 3 OHIP Maximum (Max) Score of Items 1–4 and Max Activations of the CORONAflex (ACf)

Cement	Patients	Crowns	Total max score items 1–4	Total max ACf
HT	6	20	69*	74
DUR	6	19	97	82
IMP	9	35	146	327

OHIP = Oral Health Impact Profile; HT = Harvard TEMP (temporary); DUR = Durelon (definitive); IMP = IMPROV (temporary).
*Chi-square: $P < .01$.

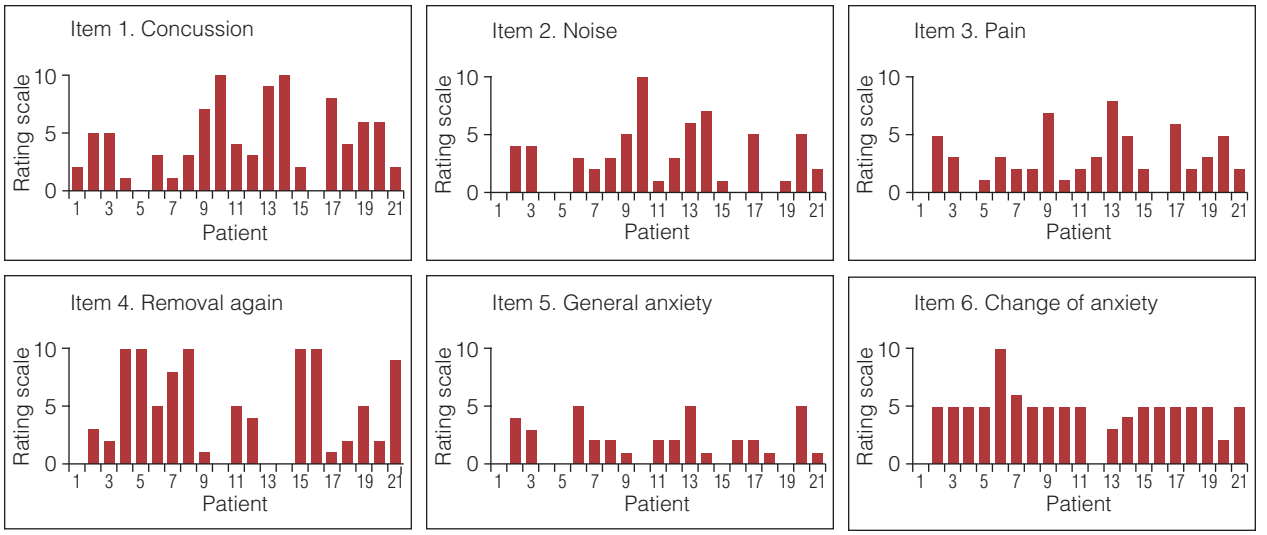

Fig 3 Patients' responses to standardized, six-item questionnaire.

3). There was a certain unwillingness (item 4) to do the removal test again, and the unpleasant experience is also expressed by the rating of item 6. Table 3 gives an overview on the total maximum ACf per cement group and the total maximum rating points for questionnaire items 1 to 4. The HT cement group exhibited significantly lower maximum rating points ($P < .01$). Table 4 exhibits the correlation (Spearman rank correlation coefficient) between ACf and the patients' rating. The correlation was weak for items 1, 2, 4, and 6 and nonexistent for items 3 and 5.

At the 2-year follow-up after implant placement, the measured crestal bone loss was as follows: mean: 0.60 ± 0.46 mm, median: 0.62 ± −1.00 to 0.44 mm. Only seven implant sites lost more than 1 mm of bone. Figures 4a, 4b, and 4c show three implants of the same patient at the three time points. This patient underwent 43 ACf actions.

Before and after the removal test no crown became loose or was damaged in any way. Thus, during the entire 2-year observation period, survival of implants and crowns was 100%.

Discussion

In this study, all 74 crowns were removed successfully and technical complications did not occur. Another study also reported successful outcomes when retrieving crowns with the CORONAflex instrument in a clinical setting,[19] and it appears that removal of cemented crowns is a viable method.[3] Nevertheless, the best way to affix implant-supported dental prostheses, ie, cementation or screw retention, is still widely disputed.[5,20–22] Biologic and technical aspects are considered and have to be weighted against each other. For natural teeth, it has been shown that the

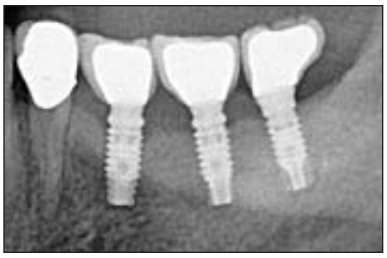

Fig 4a Four months after implant surgery when the crowns were mounted.

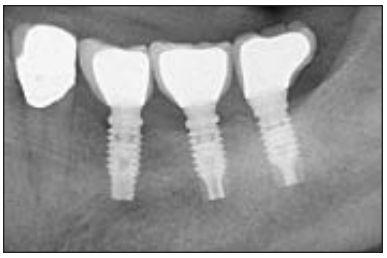

Fig 4b Twelve months after implant surgery when the crowns were removed with the CORONAflex 2005 device.

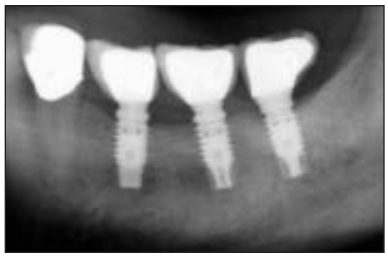

Fig 4c Twenty-four months after implant surgery when the patients answered the standardized questionnaire.

precision of fit and the marginal gap play an important role for the patient's periodontal health.[23–25] This also may be true for the health of the peri-implant tissues. Single case reports showed the problem of cement escape into the peri-implant tissue, and a subsequent inflammatory process with bone resorption has been investigated.[26] One multi-center study found slightly better peri-implant parameters, as expressed by a low Bleeding Index with screw retention versus cementation, but this did not reach a statistically significant level.[21] With cementation of the prostheses, angulated abutments can be utilized to optimize the implant axis, and better esthetics of cemented versus screw-retained crowns is reported.[27] There is no interference of occlusal contacts with the screw access hole.[5] Thus, for various reasons dentists prefer cementation for their daily clinical practice,[21] but permanent luting of implant-supported restorations often is not recommended in order to maintain retrievability.[28,29] Thus, the strength of different cements (provisional and definitive), their retention force, and cement failure were tested in various studies.[29–31]

In the present study, the strength of all three tested cements on standard titanium abutments were adequate for maintaining stability of the crowns under daily function. None of the crowns became loose during the relatively brief observation time and no technical complications occurred before and up to 1 year after the removal procedure. Equally, the air-accelerated crown remover proved to be a practical device since all of the crowns could be removed, although the number of activations was high for some crowns.

The results of this study revealed that both the abutment height and the type of cement significantly affected the number of ACfs required to remove the crown, but the cement type was more relevant. This may be surprising, but besides the height of the abutment, the geometry and design of the abutment may play a role. Interestingly, one study showed that an increased abutment height produced an increase in bond strength only for definitive cements.[32] Sandblasted and standard surfaces of abutments with a height of 4 and 6 mm were compared. The authors concluded that the surface roughness compared to the height of abutment had a greater impact on the cement strength and suggested sandblasting for achieving higher bonding strengths. Another study did not find significant differences between two cements (glass ionomer and polycarboxylate) when the crowns were removed using the CORONAflex instrument.[17] Laboratory in vitro tests with six different cements revealed a large variation of retention force within one and the same cement group and particularly among different cement groups (low strength of provisional vs high strength of definitive cements) with statistical significance.[33] In the present study, the SDs were rather high. This is also reflected by the ACf values, with a minimum ACf value of 1 and the maximum value of 38. In the IMP group, the cement that demonstrated the highest strength in the present study, the ACf values variation was particularly broad.

Besides the type of the cement, other factors influenced the clinical measurements, which may have resulted in different findings if compared to laboratory studies. The manipulation of the instrument directly in the mouth and the applied preload will influence the number of ACfs. Unlike in vitro tests, the patient is not a stable experimental setup with rigid fixation.

Table 4 Correlation Between Activations of the CORONAflex and Patients' Responses

Item	Rating median mean ± SD	Spearman rank correlation = r
1. Concussion	4 4.35 ± 3.12	0.345 weak
2. Noise	3 2.9 ± 2.71	0.312 weak
3. Pain	2 2.29 ± 2.26	0.177 —
4. Removal again	4 4.61 ± 3.94	0.387 weak
5. General anxiety	2 1.81 ± 1.71	0.102 —
6. Change of anxiety since removal	5 4.25 ± 2.06	0.333 weak

The impact of the air-accelerated crown remover may have been weakened by the elasticity of the bone and instability of the mandible. It was difficult to apply the instrument with a defined preload and to control a full axial direction for displacement of the crowns. Moreover, in the present study, the forceps had rubber-coated branches in order to avoid damage to the crowns, which probably had a damping effect. One study found that the force transmission from the CORONAflex to the implant superstructure is sometimes not reliable and the impact transferred to the crown is smaller than comparable measurements under laboratory conditions.[15] Another study showed that less activation of the instrument became necessary to remove the crowns if higher preloads were applied.[17] While laboratory tests often include storage in water to simulate the patient's oral environment, one study did not identify any effect of such artificial aging on the crown removal test. Otherwise, in the present study the crowns were all subjected to full occlusal, functional load for an 8-month period under normal in vivo conditions. This impact of functional force could either strengthen or weaken the seating of the crowns on the abutments and the retention force of the cement. Therefore, the results may be different from laboratory studies.

An abutment height of 2 mm, as it occurred in the present study, is generally not recommended. By including such short abutments, the present measurements can show the pull-off forces were lower but also that the selection of the cement and the geometry of the abutment may be important as well for retention, not only the height itself.

Experience of traumatic dental procedures in the past is often the main reason for developing dental anxiety.[34] Dental anxiety decreases oral health–related quality of life.[35] Recent data show that for 50% to 60% of the population, the dental visit is an unpleasant experience.[36] Dentists should know that possible negative psychologic impacts on patients may occur with certain manipulations and specific tools. Therefore, the patients' subjective evaluation is of interest. Comparable to the present evaluation, one study recorded the subjective assessment of the tapping procedure when doing transcrestal sinus floor elevation.[37] Although no significant pain was perceived, an unpleasant feeling was reported by several patients. From the present results, it appears that the retrospective judgment of the application of the CORONAflex 2005 device was not a traumatic experience for the patients. An increased total ACf value did not have the effect of a highly unpleasant perception of concussion, noise, or pain as remembered by the patients. One may question why the questionnaire was not administered at the end of the session of the crown removal. It was assumed that at this moment the answers would be given under the immediate unpleasant impact of the instrument. Some time later the answers may better show whether the use of the instrument was perceived as a long-term negative experience.

The rating scores when analyzed individually for four patients, who received a total ACf of $\geq$ 40, revealed an increase for all six items as compared to the remaining patients. One patient with a total of four crowns (cemented with IMP) who received a total of 93 ACfs, recalled pain and fear of damage to the implants and, thus, would be completely against the use of the device in the future. In fact, the scores for items 1 to 4 were significantly lower in the HT group—with a lower number of ACfs—as compared to the DUR and IMP groups.

Conclusions

Retrievability of cemented implant crowns is possible with different types of cement. The strength of definitive cements appears to be high; therefore, the selection of an appropriate cement type may be critical for long-term use. The KaVo CORONAflex 2005 device can be applied for crown removal and, in general, is well accepted by patients. The impact on the patients' subjective perception should be taken into account, however.

Acknowledgments

The authors reported no conflicts of interest related to this study.

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