Method of Retention Control for Compromised Periodontal Bone Support Abutment of Conical Crown Retained Denture

Chau-Hsiang Wang,[1,2] Huey-Er Lee,[1,2] Ting-Hsun Lan,[1,3] and Yoshimasa Igarashi[4]
[1]Department of Prosthodontics, Kaohsiung Medical University Hospital, [2]Faculty of Dentistry, College of Dental Medicine, Kaohsiung Medical University, Kaohsiung, [3]Department of Dentistry, Antai Medical Care Cooperation, Antai Tian-Sheng Memorial Hospital, Pingtung, Taiwan, and [4]Department of Masticatory Function Rehabilitation, Division of Oral Health Sciences, Graduate School, Tokyo Medical and Dental University, Tokyo, Japan.

Conical crown-retained dentures (CCRD) show a higher survival rate and greater patient satisfaction than transitional removable partial dentures during long-term follow-up. However, unsustainable denture retention force on supporting abutments after initial delivery and loss retention are frequently seen in long-term follow-up of clinical cases. The main causes are insufficient information concerning denture retention designs and the retention-tolerance of the supporting abutments. Monitoring by dental technicians of the quality of dental prostheses is critical. This case report describes an optimal method for CCRD construction that determines and distributes an optimal denture retention force on the supporting abutments to allow the patient to easily remove the denture while ensuring that the CCRD remains in place during physiologic activities. Oral rehabilitation with CCRD should consider the condition of the abutment periodontal support, the interarch occlusal relationship, supplemental fatigue of the terminal abutment, and patient's estimated bite force. The effects of friction on the abutment's inner crown were based on an optimal α angle. The dental laboratory used these measurements to fabricate a CCRD using a Koni-Meter to adjust the retention of the inner crown. This method protects the abutments and reduces the wear between the inner and outer crowns. The CCRD achieved good esthetic results and physiologic functions. Periodic long-term follow-up of the patient and CCRD after initial placement is recommended.

Key Words: Ante's law, conical crown-retained denture, removable partial denture, retention, root surface area
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Since Körber's [1] explanation of the mechanical and physiologic properties of conical crown-retained dentures (CCRDs) in the 1960s, these dentures have become established for use in clinical partial denture rehabilitation. In long-term observational follow-up studies, CCRDs show a higher survival rate and greater patient satisfaction than traditional removable partial dentures [2–6]. Nevertheless, loss of retention of inner crowns, loss of resin veneer and breakdown of outer crowns, as well as fracture of the denture frame

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Address correspondence and reprint requests to: Dr Ting-Hsun Lan, Department of Prosthodontics, Kaohsiung Medical University Hospital, 100 Tzyou 1st Road, Kaohsiung 80756, Taiwan.
E-mail: TingHsun.Lan@gmail.com

or abutment, are common problems in CCRD prostheses [5–8]. These mechanical problems are caused by wedging between the inner and outer crowns, particularly in cases of over-retention and long-term use.

Correct design and fabrication of CCRDs are essential to avoid these problems. The design of a CCRD should provide sufficient retention and protect the abutments from damage. The method presented in this case report describes a technique for constructing a CCRD, which controls the denture's retention and optimizes the retention force in the supporting abutments, while effectively distributing the functional retention to each abutment.

Case Presentation

A 78-year-old partially edentulous female patient of medium stature requested maxillary and mandible prostheses. Physical examination and medical history were unremarkable. Various removable partial denture designs were presented to the patient. CCRDs were selected to restore both the maxillary and mandibular arches, as shown in Figure 1.

Six teeth (#44, #43, #31, #32, #33 and #35 in Fédération Dentaire Internationale World Dental Federation nomenclature) were present in the mandibular arch. Due to poor periodontal bone support and an uncertain prognosis, metal copings were placed on teeth #31 and #32 after endodontic treatment. Teeth #44, #43, #33, and #35 were selected as abutments for the CCRD.

Seven teeth (#14, #12, #11, #22, #23, #24 and #25) were present in the maxillary arch. A porcelain fused-to-metal fixed bridge was restored from tooth #11 to #23, with teeth #14, #12, #24 and #25 used as abutments for the CCRD. After calculating the retention force needed for each abutment, it was determined that a konometric device and konometer should be used to ensure sufficient retention of the inner and outer crowns. The following description summarizes the steps used to design the maxillary CCRD.

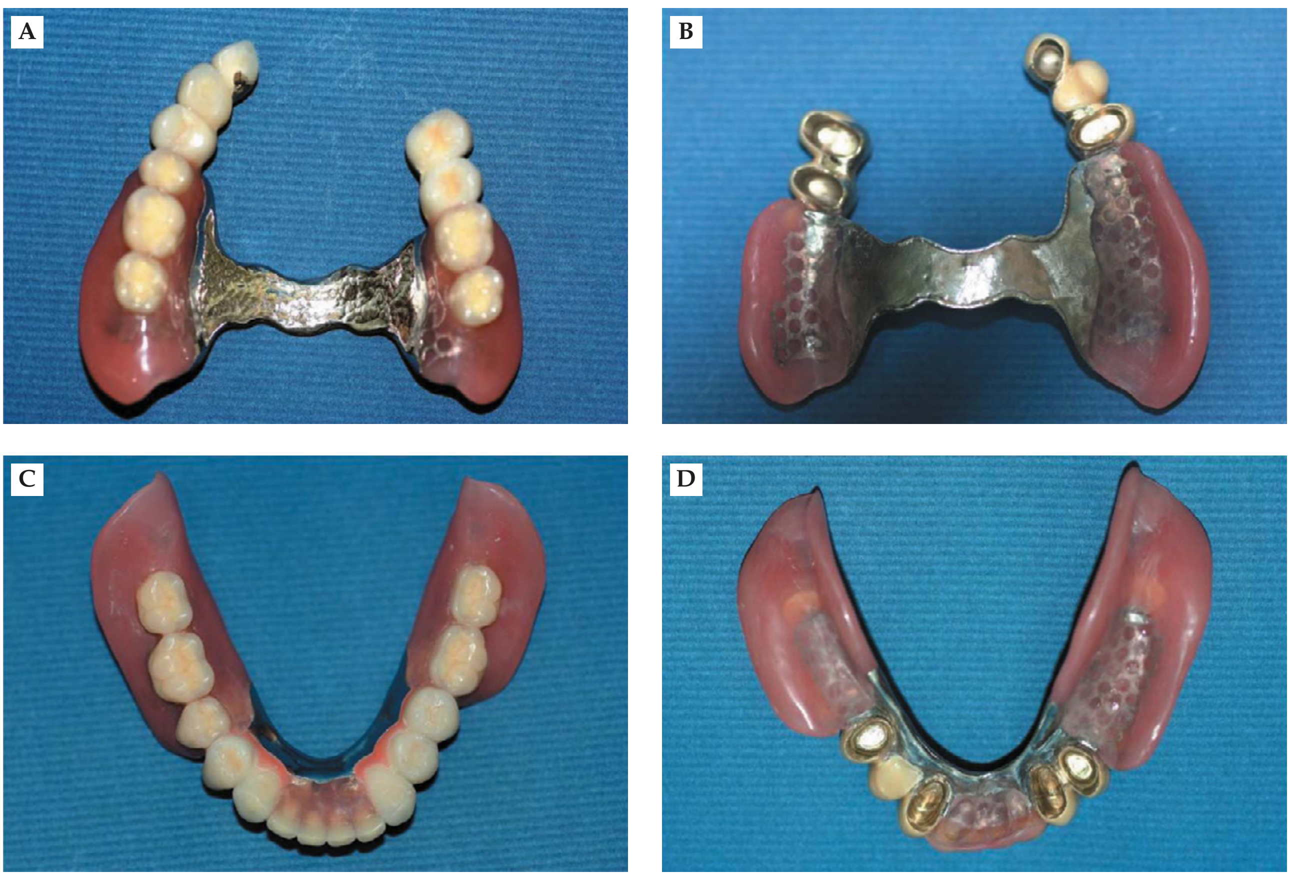

Figure 1. *Final conical crown-retained dentures for the maxilla and mandible.*

Step 1: Calculation of the Residual Periodontal Support Index (RPSI) of the abutments

We measured the bony support and estimated the root length of each abutment tooth from periapical X-rays (Figure 2). A standard X-ray using a paralleling technique is necessary for this measurement. The root length was estimated from the distance between the root apices to 2 mm short of the cementoenamel junction. The bone level was then calculated by dividing the bony supporting height by root length.

The RPSI for each tooth was calculated based on the values in Tables 1 and 2 derived from Osada et al [9]. The RPSI values for abutments #14, #12, #24 and #25 were 3.38, 0.71, 3.33 and 2.88, respectively (Table 3).

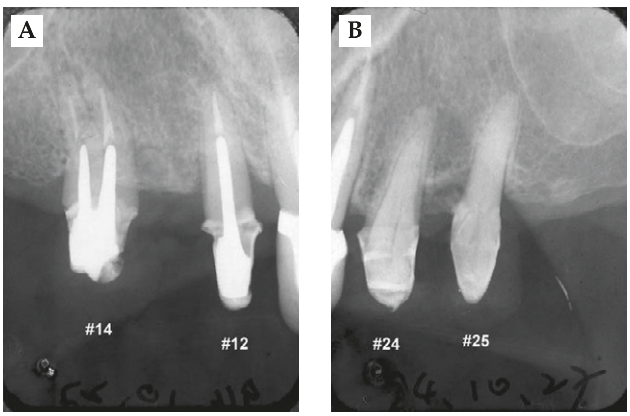

Figure 2. *Periapical X-rays of the maxillary abutments.*

Step 2: Calculation of the Ideal Periodontal Support Index (IPSI) of the abutments

The RPSI should be modified to the IPSI based on the concept of mechanical strategic tooth position. As stress is concentrated on the terminal abutment [10,11], Yamazaki et al [11] emphasized that the RPSI of the terminal abutments should deduct the supplemental fatigue value to determine the IPSI. In this case, the IPSI value of the terminal abutments #14 and #25 were deducted from supplemental fatigue value 1 to become 2.38 and 1.88, respectively (Table 3). The total ideal periodontal support index (TIPSI) is determined by summing the IPSI values. In this case, the TIPSI was 8.30.

Step 3: Calculation of the unit IPSI values and their burden retention force

Each IPSI unit burden retention force is obtained from a denture's minimum required retention divided by the TIPSI. Assuming the minimum required retention [12,13] for a maxillary denture is 2,800 gf (gram-force) and the denture base generates retention of 300 gf, the CCRD abutments will need to generate a retention force of 2,500 gf [13]. According to Igarashi et al [14], the retention between the inner and outer crowns of the CCRD will gradually decrease due to wear and stabilization after 5,000–10,000 removals and insertions. At that time, 4–5% of the retention force will have been lost, resulting in 95–96% of the initial retention.

Table 1. Relative ratios of relationships between bone height and residual root surface area of maxillary teeth

Maxilla / Bone level	Tooth position						
	Central incisor	Lateral incisor	Canine	1st premolar	2nd premolar	1st molar	2nd molar
1.00	2.00	1.00	5.00	4.00	4.00	6.00	6.00
0.95	1.90	0.95	4.75	3.76	3.76	5.73	5.71
0.90	1.81	0.90	4.51	3.52	3.51	5.47	5.42
0.85	1.71	0.86	4.26	3.28	3.27	5.20	5.13
0.80	1.62	0.81	4.01	3.05	3.02	4.93	4.84
0.75	1.52	0.76	3.77	2.81	2.78	4.67	4.55
0.70	1.39	0.70	3.46	2.58	2.54	4.27	4.17
0.65	1.25	0.64	3.15	2.36	2.31	3.88	3.79
0.60	1.12	0.57	2.84	2.13	2.07	3.49	3.41
0.55	0.98	0.51	2.54	1.91	1.84	3.09	3.03
0.50	0.85	0.45	2.23	1.68	1.60	2.70	2.65
0.45	0.74	0.40	1.97	1.48	1.41	2.33	2.32
0.40	0.64	0.34	1.71	1.27	1.22	1.97	1.98
0.35	0.54	0.29	1.45	1.07	1.04	1.60	1.64
0.30	0.43	0.24	1.19	0.86	0.85	1.23	1.31
0.25	0.33	0.18	0.93	0.66	0.66	0.86	0.97

Table 2. Relative ratios between bone height and residual root surface area for mandibular teeth

Mandible / Bone level	Tooth position						
	Central incisor	Lateral incisor	Canine	1st premolar	2nd premolar	1st molar	2nd molar
1.00	1.00	1.00	5.00	4.00	4.00	6.00	6.00
0.95	0.96	0.95	4.74	3.76	3.75	5.71	5.68
0.90	0.91	0.90	4.48	3.51	3.50	5.41	5.36
0.85	0.87	0.86	4.23	3.27	3.26	5.12	5.04
0.80	0.83	0.81	3.97	3.02	3.01	4.82	4.71
0.75	0.78	0.76	3.71	2.78	2.76	4.53	4.39
0.70	0.72	0.70	3.39	2.55	2.53	4.16	4.06
0.65	0.66	0.64	3.08	2.32	2.30	3.80	3.72
0.60	0.60	0.58	2.76	2.09	2.07	3.43	3.38
0.55	0.54	0.52	2.45	1.86	1.84	3.07	3.05
0.50	0.47	0.46	2.13	1.63	1.60	2.70	2.71
0.45	0.42	0.41	1.87	1.43	1.42	2.37	2.39
0.40	0.36	0.36	1.60	1.24	1.23	2.04	2.07
0.35	0.31	0.30	1.34	1.04	1.04	1.71	1.75
0.30	0.25	0.25	1.07	0.84	0.85	1.38	1.43
0.25	0.20	0.20	0.81	0.65	0.66	1.05	1.11

Table 3. Parameters for maxillary conical crown-retained dentures

Tooth*	Bone level	RPSI	Terminal abutment supplemental	IPSI	Estimated retention (gf)	Designed α angle (°)
14	0.87	3.38	–1	2.38	747	11.5
12	0.74	0.71	–	0.71	223	12.5
24	0.86	3.33	–	3.33	900 (1,046)	11.0
25	0.72	2.88	–1	1.88	590	11.5
Total		10.30	–2	8.30	2,460	

*Fédération Dentaire Internationale World Dental Federation teeth numbering system. RPSI = Residual periodontal support index; IPSI = ideal periodontal support index.

Therefore, the initial retention should be 2,604 gf (2,500/0.96) to account for the loss in retention force over time. Dividing 2,604 gf by the TIPSI provided a unit IPSI burden retention force value of 314 gf (2,604/8.30).

Step 4: Calculation of the burden retention force for each abutment

To calculate the retention force of each abutment, the unit IPSI burden retention force value (from step 3) is multiplied by each abutment's IPSI value. The estimated burden retention force for the abutments to tooth #24 was 1,046 gf (314 × 3.33), which exceeded the permitted physiologic limit for the upper tooth (900 gf) [15]. Thus the burden retention force for tooth #24 was adjusted to the physiologic limit of 900 gf. The burden retention forces for the other abutments are listed in Table 3. The total estimated retention force of all abutments was 2,460 gf, which differs only slightly from the expected value (2,604 gf).

Step 5: Estimation of the α angle of the inner crown (konometry)

Given that our patient was elderly and of medium stature, the estimated bite force [16] was low (occlusal force $F_A = 4$ kgf). Using a theoretical inference chart for the "relationship between the retention and α angle of the inner crown" [17], the α angle for the abutment's inner crown was determined to the closest minimum angle (Table 3).

Step 6: Adjusting the retention of the inner and outer crowns

The abutment's inner crown α angle should be communicated to the dental laboratory where the

Table 4. Various parameters for mandibular conical crown-retained dentures

Tooth*	Bone level	RPSI	Terminal abutment supplemental	IPSI	Estimated retention (gf)	Designed α angle (°)
35	0.95	3.75	–1	2.75	514	12.0
33	0.91	4.54	–	4.54	849	11.0
43	0.81	4.02	–	4.02	752	11.5
44	0.92	3.61	–1	2.61	488	12.0
Total		15.90	–2	13.92	2,603	

*Fédération Dentaire Internationale World Dental Federation teeth numbering system. RPSI = Residual periodontal support index; IPSI = ideal periodontal support index.

konometric device can be used to manufacture inner crowns according to their α angles. Figure 3 summarizes the laboratory production of the CCRD for the present case. Other procedures followed routine CCRD manufacture fabrication methods. After try-in of the inner crowns was completed, the outer crowns were designed and fabricated. After the inner and outer crowns were completed, a Koni-Meter (Krupp, Essen, Germany) was used to measure the retention force of each pair of inner and outer crowns. Figure 4 shows the Koni-Meter in use. The retention of each pair of inner and outer crowns was adjusted to match the previously determined retention force.

The retention force distribution and calculation procedures for the mandibular CCRD with four abutments (#33, #35, #43 and #44) were the same as those for the maxillary CCRD. Their calculation, estimate, procedures and numerical values are summarized in Table 4. Thereafter, routine procedures were followed to deliver the dentures.

Step 7: Maintenance and periodic follow-up

The CCRDs were delivered after final occlusal adjustment. Balancing occlusion was selected in this case owing to the distal free end of the maxilla and mandible. Apart from initial adjustments of the denture base, the denture was easy to remove and the abutments exhibited no sign of looseness. The patient was very satisfied with the denture.

Discussion

In clinical practice, the retention of a CCRD is often inadequate or, more often, exceeds optimal values. Over-retention is commonly seen in the clinic. To achieve optimal retention, the clinician needs to consider the abutment's physiologic condition. The retention force for each abutment should not exceed the normal tooth physiologic limit but should achieve the denture's required retention. Over-retention of partial dentures should be avoided to prevent difficulties in removal by the patient and prevent trauma to the abutments. Over-retention can also increase attrition leading to loss of retention.

Ideally, the CCRD should be designed to retain stable retention without over- or under-retention. The minimum required retention is preferred [18] to allow the patient to easily remove the denture while ensuring that the CCRD remains seated during physiologic activities (e.g. drinking, eating, speaking and yawning). Over-retention of a CCRD can loosen the inner crown or abutments, cause trauma or fracturing of the root, or may damage the denture. Over-retention can also cause excessive wear of the inner and outer crowns leading to denture instability. All of these problems can lead to denture failure. CCRDs are prone to over-retention, particularly in cases with multiple abutments; therefore, CCRDs with five or more abutments are not recommended [19].

Without careful planning and design, the minimum required retention of a CCRD with multiple abutments can be exceeded. This article suggests a practical method to reasonably and effectively determine and distribute the retention forces in a CCRD. Therefore, cooperation between the laboratory and clinic is very important to produce the denture that fulfills the clinical requirements.

Each abutment cannot carry more retentive load than its physiologic tolerable limit. However, numerous factors determine the physiologic tolerable limit in a periodontally compromised abutment, which complicates the clinical decision-making. During manufacture, inattention to tolerance can easily result in

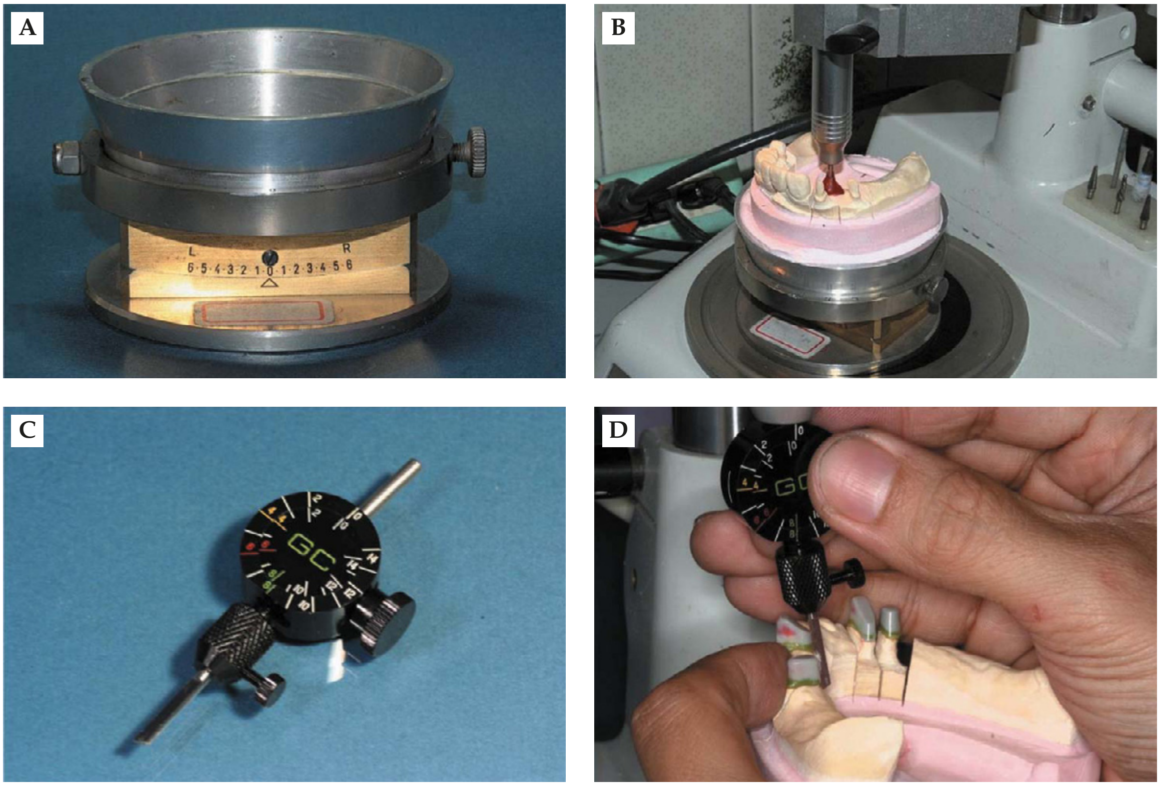

Figure 3. *Views of the inner crowns in wax with the designed α angle (konometry). (A) Konometric device (Wieland's konuscchillten). (B) Aligning the insertion path using the cemented pin technique. (C) Konometer (GC's Conometer). (D) Wax models of the inner crowns.*

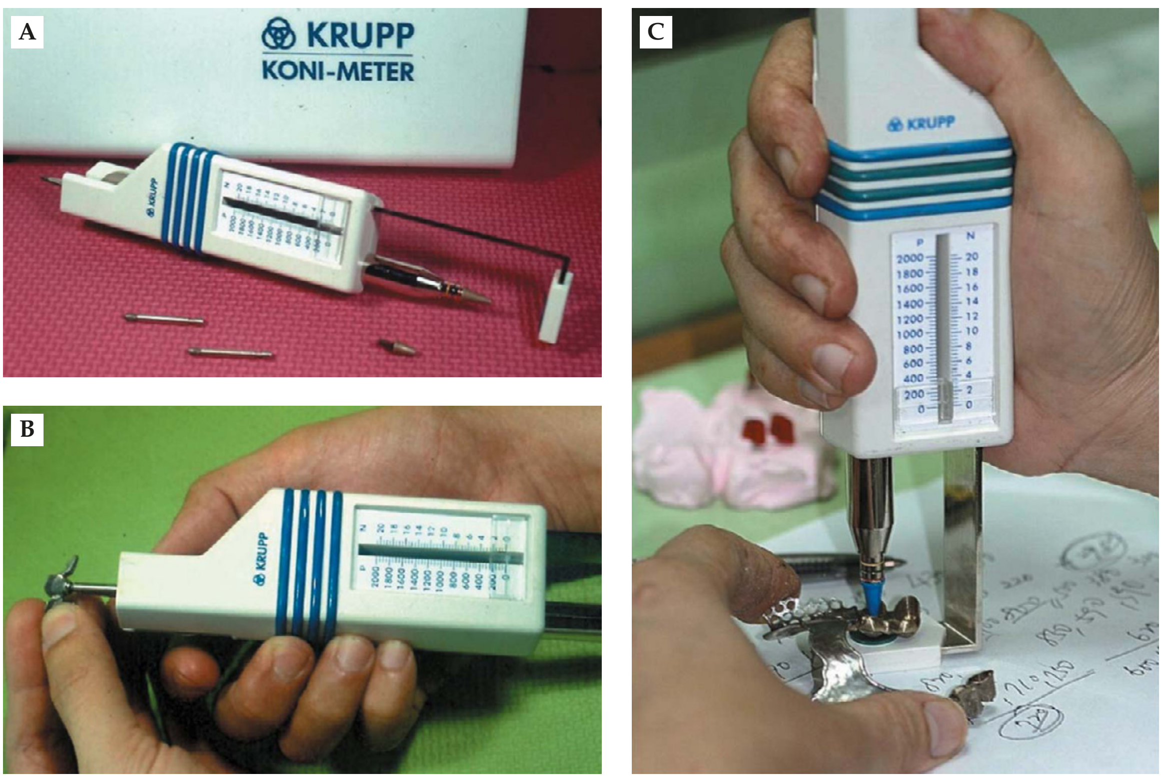

Figure 4. *(A) Image of the Koni-Meter. (B) Simulating the correct occlusion force using the Koni-Meter. (C) Adjusting the retention of the inner and outer crowns to reach the intended retention force.*

abutments surpassing the acceptable limit, which may result in failure. The retention load distributed to each abutment of a CCRD should be as low as possible to avoid damaging the abutment, while maintaining adequate retention.

According to Siba, the minimum required retention of a denture should be between 2–3 kg [12]. Similarly, Sugiyama noted that a denture's retention should not be less than 2,000 g [13]. If the retentive force is less than this value, the denture may be dislodged during functional movement. The ideal denture retention force should range from 2,500 g to 3,000 g.

With the exception of a retention provided by retainers, the retention of a removable partial denture is derived from the base of the denture and muscle adaptation to the denture periphery [20]. Numerous factors affect the retention from these sources, including saliva consistency/viscosity and amount, the fitness and extension of the denture base, and the peripheral seal. Because these factors are numerous and difficult to control, the retention force provided by the denture base can only be estimated by experience. Practically, the retention force provided by the denture base may be slightly higher in the maxillary arch with a wider palatal area. Minagi et al [21] described a similar technique for CCRD, where each telescopic crown was adjusted to provide a retentive force of approximately 9.8 N. However, the conditions were limited due to the health of the periodontal supporting tissue [15]. When the periodontal supporting tissue is damaged, the present method provides a better approach to evaluate the retention of each abutment.

"Ante's law" [22] suggests that the supporting ability of the periodontium is underestimated. However, several follow-up reports [23,24] have shown a significant relationship between the root surface area and the success rate of prostheses. Therefore, it is reasonable to distribute the retention to each abutment according to the ratio of IPSP to TIPSP.

Jepsen measured the root surface area using radiographs [25]. In clinical practice, a comparison between teeth and the relative ratios of root surface area of teeth is commonly seen [26]. However, the use of radiographs (which provide a two-dimensional image) may lead to inaccurate measurements of the surface area of a three-dimensional root. Other methods to measure the root surface area (e.g. the vinyl acetate coating method described by Cauchie [27], Vest [28], or Haga et al [29]) should be more reliable. The root surface area relative ratios for the central incisor, lateral incisor, canine, first premolar, second premolar, first molar, second molar in the maxillary arch are 2, 1, 5, 4, 4, 6 and 6, respectively, with values of 1, 1, 5, 4, 4, 6 and 6, respectively, in the mandibular arch (Tables 1 and 2).

When the periodontal supporting tissue is damaged, the relative ratio can be difficult to determine. For example, when the periodontal tissue is reduced to half of its normal height, it is not unreasonable to assume that the root surface area is decreased by 50%. However, the root is not cylindrical in shape, but rather displays a tapered cone-shape with variations in concavity or curvature, or with additional roots. Thus, if half of the height of the alveolar bone is lost, the supporting root surface area will be < 50% with a greater loss in more tapered roots. The root surface area data reported by Osada et al [9] and Haga et al [29] demonstrate the relationship between alveolar bone height and residual root surface area. Tables 1 and 2 are modified from the data reported by Osada et al [9] derived using the interpolation method.

According to a theoretical formula [17], the retentive force (F_R), inner crown angle (α angle) and occlusal force (F_A) for a CCRD is described by the following equation:

$$F_R = F_A \times [\mu_0 - \tan(\alpha/2)] / \sin(\alpha/2)$$

where μ_0 is the frictional coefficient between the inner and outer crown.

From this formula, it is clear that the occlusal force and frictional coefficient are positively correlated to the retentive force. Table 5 assumes μ_0 of 0.12 and F_A of 4, 5 and 6 kgf, with the $\alpha/2$ angle of the inner crown yielding F_R. The retention control from each abutment

Table 5. Theoretical retention force, given a frictional coefficient of 0.12 and occlusal force of 4, 5 or 6 kgf and the $\alpha/2$ angle of the inner crown creates the retention force*

$\alpha/2$	$F_A = 4$ kgf	$F_A = 5$ kgf	$F_A = 6$ kgf
1°	23.50*	29.38	35.25
2°	9.75	12.19	14.63
3°	5.17	6.46	7.75
4°	2.87	3.59	4.31
5°	1.49	1.87	2.24
6°	0.57	0.71	0.86

*kgf. F_A = Occlusal force.

to the prosthesis delivery is very important. There are several steps involved in developing a CCRD; if errors occur at any stage in the denture making process, the process should return to the previous stage to ensure the final retention is developed as intended based on the initial designs.

Although the CCRD for this patient has provided good clinical results to date, periodical follow-up is very important to monitor outcomes. Further studies of CCRDs are needed to explore the numerous factors that may influence retention and clinical outcomes.

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針對牙周支持不佳支台齒的套疊式活動義齒固位力控制的方法

王兆祥[1,2] 李惠娥[1,2] 藍鼎勛[1,3] 五十嵐順正[4]

[1]高雄醫學大學附設醫院 牙科部補綴科

[2]高雄醫學大學 口腔醫學院 牙醫學系

[3]屏東東港安泰醫療社團法人安泰醫院 牙科部

[4]日本東京齒科大學 口腔健康科學部 咀嚼功能重建科

套疊式活動假牙在長期的觀察下比傳統假牙有更高的滿意度及預後。然而，剛裝戴時的固位力過強與長期固位力變弱的臨床病例屢見不鮮。主要的原因正是對於整體假牙固位力設計及支臺齒的承受程度的判斷資訊不足，另外，針對牙科技師補綴物品質的監測在臨床上也是非常重要的。本病例針對套疊式活動義齒的支台齒提供一個更理想、更易控制固位力且使假牙維持生理性功能的方法。這一類使用套疊式活動義齒進行全口重建的病患需要考慮支台齒的牙周支持情況、上下顎咬合關係、末端支台齒的疲勞補償係數及估計病患的咬合力。決定摩擦力以製造固位力的內冠設計在於精準的計算出所需的內冠角度（α）。牙科技師依照醫師給予的訊息製作內冠角度並使用儀器（**Koni-Meter**）調整所需要的固位力。本方法配合定期牙周維護可以保護支台齒並減少內外冠的磨耗率達到長期的預後並獲得基本美觀與生理性功能。

關鍵詞：Ante's law，套疊式活動義齒，活動義齒，固位力，牙根表面積

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通訊作者：藍鼎勛醫師
高雄醫學大學附設醫院牙科部補綴科
高雄市自由一路 **100** 號