Literature Review

Types of clinical application of rotational path removable partial dentures: a literature review.

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Introduction

Rotational path of insertion has been applied in removable partial prosthesis for decades. Although the term of 'rotational path of insertion' was not yet established in 1958, Mann[1] proposed the concept of rotary path by using Hart-Dunn attachment in unilateral distal extension removable partial denture design. The system was reintroduced in nineteen seventy by many authors[2-4] and presently, the term 'rotational path of insertion'[5] was widely accepted. Missing anterior teeth and missing posterior teeth with tilted mandibular molars were the most popular situations reported. Other clinical applications were also described in the following years,[5-13] but were not received considerable attention.

A questionnaire survey described by Jacobson in 1994,[14] members of the Academy of Prosthodontics in the United States were asked to provide responses. Eighty percent of respondents believed that they fully understood the concept of rotational path of insertion and 50% of respondents used the technique in situations that required the elimination of clasps and experienced long-term favorable success rates. Possible reasons of the other half of respondents not using the technique may be due to lack of sufficient understanding of the concept, absence of documented evidence of long-term clinical success, a general lack of confidence in the efficacy of the procedure as described in the literature and difficulties in obtaining knowledgeable laboratory support.

Rotational path of insertion is a feasible treatment modality, but it is underutilized[15,16] or overlooked.[17,18] For encouraging its application, more investigation to clarify the rationale and criteria in the application of rotational path is needed. Therefore, the aim of our study is to collect previous publications that described and discussed the clinical application of rotational path of path in web wide or other resources. Types of clinical situations appropriate to apply rotational path of insertion for removable partial denture design are analyzed and the overall scope of clinical application of the technique is determined.

Material And Methods

Four electronic resources (PubMed, Medline + Journals @ Ovid, ScienceDirect and Google scholar) were used to identify the articles about rotational path of insertion from January 1, 1970

to December 31, 2020. Keyword combinations were rotational path, rotational path of insertion, rotational path removable partial denture, dual path, dual path of insertion, aesthetics, with the prefix 'AND' and 'OR'. In addition, the cited references in the identified articles were also manually assessed for searching relevant articles that were probably missed. Then, the identified articles were screened to exclude the articles not using English language, not mentioning rotational path, not discussing clinical application, original research articles, abstract, reader's round table, comment, poster, and duplicates. Finally, the eligible articles related to clinical report or clinical technical discussion were included in the study for analysis.

The full text articles were then reviewed to identify the various types of rotational path removable partial denture applied in different clinical situations. The characteristics of each type of clinical application such as Category classification, insertion direction and sequence, and Kennedy classification were determined and recorded. The screening and reviewing procedures were performed by two reviewers (L.F.C. and L.Y.H.) independently and any disagreement was resolved by discussion with a third reviewer (L.K.C.) if required.

Results

Our search identified 106 articles including 95 from journal publications and 11 from textbooks from January 1, 1970 to December 31, 2020 . After screening, 48 articles were excluded and 58 articles related to clinical report or clinical technical discussion were finally included in the study for analysis. The study flow chart was illustrated in Figure 1. Nine types of clinical application of rotational path of insertion (RP1-RP9) were determined. RP5 had three different designs for different purposes, and therefore was denoted as RP5a[19,20], RP5b[6,8] and RP5c[10,21]. The number and percentage of articles related to each application type was shown in Table 1. RP1 to RP6 were applied in the tooth bounded situations and RP7 to RP9 were applied in distal extension situations.

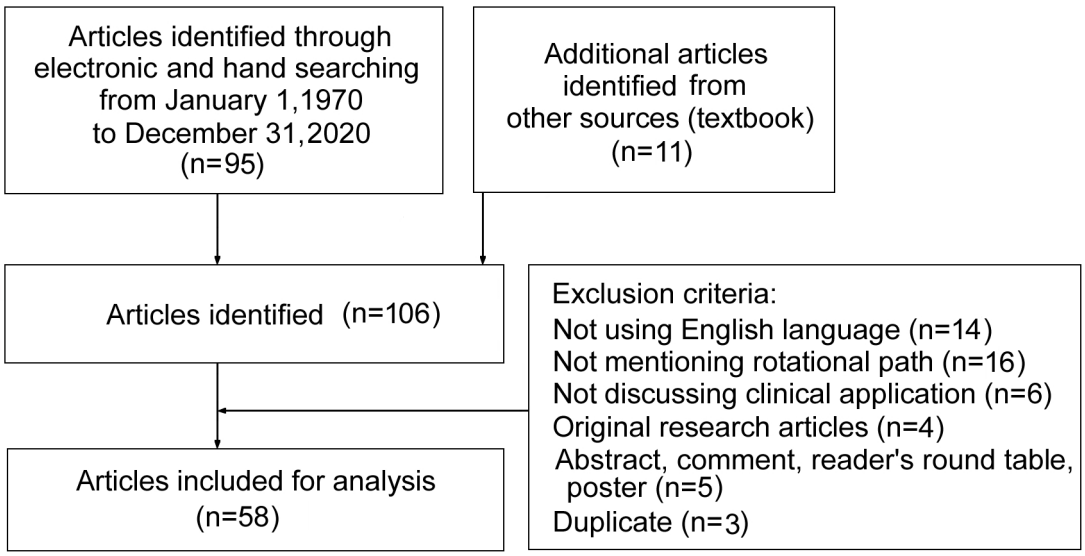

Figure 1. Study flow chart.

Table 1. The number and percentage of articles related to each application type.

Clinical application type	Number	Percentage [a]
Missing anterior teeth (RP1)	44	76%
Bilateral missing posterior teeth with tilted mandibular molars (RP2)	18	31%
Bilateral missing posterior teeth with aesthetic demands (RP3)	17	29%
Unilateral tooth bounded space with tilted abutment (RP4)	1	2%
Unilateral tooth bounded space with missing anterior and/or posterior teeth (RP5)	12	21%
Flaring anterior abutment, tooth bounded (RP6)	3	5%
Flaring anterior abutment, distal extension (RP7)	2	3%
Kennedy Class II without modification or space restored with fixed prosthesis (RP8)	3	5%
Kennedy Class II with modification, with tilted molar (RP9)	2	3%

[a] percentage=number of articles related to the type/total number of articles included (n=58)

The most popular clinical application type was missing anterior teeth (RP1) that was discussed in 44 articles of the all 58 records. The second and the third were bilateral missing posterior teeth with tilted mandibular molars (RP2) and bilateral missing posterior teeth with aesthetic demands (RP3) being 18 and 17 articles, respectively. Unilateral tooth bounded space with tilted abutment (RP4) had only one article published in the dental literature and flaring anterior abutment, tooth bounded (RP6) was discussed by the same author in his consecutive editions of the textbook. There was no invention in clinical application of rotational path of insertion published in the dental literature after 2008. The main contents of the articles reviewed were mainly design description, design concept, case selection, indication, contraindication, technical, and laboratory considerations for general or special type of rotational path removable partial dentures. Case reports were relatively uncommon. There were only twenty case reports (35%) out of all 58 reports, and fifteen of them described missing anterior teeth cases.

The result of analysis showed that each type of clinical application of rotational path of insertion possesses their unique characteristics including Category classification, insertion sequence, Kennedy classification and main purposes (Table 2).

Discussion

Rotational path of insertion can be classified by two methods. The first one is Category classification suggested by Jacobson[5,22] which is classified according to the position of the rotation center. Category I denture has its rotation center at the end of a long occlusal rest (Fig 2) and Category II has its rotation center at the most gingival extension of minor connector of rigid retentive components (Fig 3). The second one suggested by Krol[6] is a type of rotational path which is classified according to the sequence of insertion. There are three insertion types: anterior-posterior (A-P) type (Fig 3), posterior-anterior (P-A) type (Fig 2) and lateral (right to left or left to right) type (Fig

Table 2. Characteristics of each type of rotational path applications.

Application type	Category	Insertion sequence	Kennedy classification	Main purposes of design
RP1	II	A-P	Class III or IV	Aesthetics
RP2	I	P-A	Class III	Engage proximal undercuts
RP3	I	A-P	Class III	Aesthetics
RP4	I	P-A	Class III	Engage proximal undercut, unilateral denture
RP5a	II	Lateral or diagonal	Class III or IV	Aesthetics
RP5b	I	Lateral or diagonal	Class III or IV	Aesthetics
RP5c	I	Lateral	Class III or IV	Avoid breaking occlusal integrity
RP6	I	A-P	Class III	Aesthetics, cervical placement of labial clasp
RP7	II	Lateral or A-P diagonal	Class II	Aesthetics, cervical placement of labial clasp
RP8	I	Lateral	Class II	Avoid breaking occlusal integrity
RP9	I	P-A diagonal	Class II with modification	Engage proximal undercut

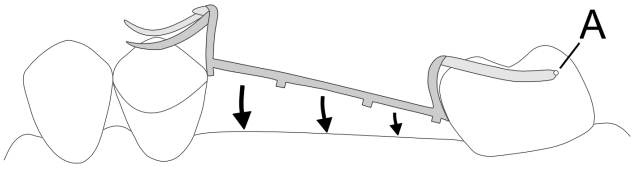

Figure 2. Schematic drawing of bilateral missing posterior teeth with tilted mandibular molars situation (RP2). It is a Category I, posterior-anterior insertion design with its rotation center (A) at the end of a long occlusal rest.

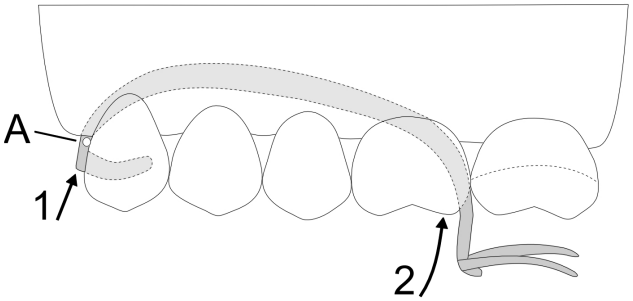

Figure 3. Schematic drawing of missing anterior teeth situation (RP1). It is a Category II anterior-posterior insertion design with its rotation center (A) at the most gingival extension of minor connector of rigid retentive components.

4). Category classification is related to position of rotation center influencing to the related undercut, retention, and the amount of block-out which will be changed from the conventional to the rotational path design; therefore, the changes should be considered by dentists and technicians. The type classification is related to the insertion sequence which gives the sense to the patient or technician how to insert the denture correctly. A diagonal rotation was mentioned by Ancowitz[23] to describe the insertion direction of the rotational path in some situations. Therefore, in our study, a diagonal type (Fig 5) is added into this classification (anterior-right to posterior-left; anterior-left to posterior-right; posterior-left to anterior-right or posterior-right to anterior-left) to provide more precise descriptions of the direction and sequence of rotational path of insertion.

There are nine types of clinical situations appropriate to apply rotational path of insertion in removable partial denture design. Each type of application possesses their unique characteristics and special designs to accomplish their purposes. Each type of clinical application is briefly described as follows.

Missing anterior teeth (RP1, Fig 3 and 6)

Missing anterior teeth is the most popular topic reported in rotational path removable partial dentures. It may be related to its effective improvement in aesthetics by removing unsightly clasp on the anterior abutments and maintaining sufficient retention. Many authors[3,4,7,9,19,22,24-30] discussed the limitation of application including the number of missing teeth, ridge form and distal extension case. It is not suitable to apply in situations with less than three missing teeth[3,4,24] because part of metal of minor connector may be shown out.[25] Sometimes, a smaller or less obvious metal finger can be substituted.[25] A large residual ridge extending anterior to the abutment teeth and rotation axis may prevent the rigid retainers reaching the area of rotation and cause laboratory and clinical difficulties.[26] Rotational path of insertion is generally not advised to apply in distal extension situations [7,9,27] because the rigid retainers will torque the abutments during rotational movements in function.[27] On the other hand, some authors agreed the application on the condition that judicious abutment selection,[22,28] firm residual ridge,[9] functional impression,[22,28] stress-breaker design,[19,22] regular close follow up and relining,[22,28] spring clasp (Twin-Flex clasp)[25,29] or modified circumferential clasp (snubber clasp)[30] were considered.

Bilateral missing posterior teeth with tilted mandibular molars (RP2, Fig 2 and 7)

It is the second popular topic in the rotational path removable partial dentures reported in the literature. The rationale and concept of this application type were fully discussed[5-8,19,22] but a complete case report has not been published. Tilted mandibular molars having undercut at mesial or mesio-lingual area, where removable partial denture is difficult to approach by conventional clasping.[3,5,6,19,20,31,32] In this rotational path design, conventional clasps on the molars are replaced by the rigid retainers of the first segment of rotational path removable partial denture, which lock into the mesial undercuts[17] and resolve the clasping problem.[8] However, patient selection should be made carefully in this application. The conditions such as shape of arch,[7,8,19,20] length of edentulous space,[7] multiple edentulous space,[8,19,20,28,33] vertical position of anterior and posterior abutment,[7] lingually tilted teeth,[8,19,20,28] projections of soft tissue and bone[7] excluding to use the rotational path were discussed. If indicated to utilize, precise laboratory works are mandatory to accomplish successful prosthesis. Special block-out procedures over some areas such as distal surfaces of the anterior abutments should be performed.[5] Some authors[5-8,17,19,20,22,24,28,33] suggested to use calipers or dividers but a specially designed block-out instrument[34] provides more precise result.

Bilateral missing posterior teeth with aesthetic demands (RP3, Fig 8)

The design concept of this application is like RP2 but with a reverse insertion sequence. It is usually applied in the maxillary arch for aesthetic reasons, as this design eliminates buccal and lingual clasps of anterior abutments.[8] In RP2 design, rotation axis is on the distal end of long occlusal rest of tilted molars and in this design, the rotation axis is changed to anterior end of occlusal rest of the canine or premolar. Canine or premolar is usually in an up-righting position, so their distal undercut is relatively less. Therefore, the distal contours of the anterior abutment teeth permitting the use of rigid retainer is crucial to the success of this design.[8,17,32] Placement of cast restoration[5,14,35,36]or bonded composite resin restoration[36,37] may be required to provide proper proximal tooth contours.

Unilateral tooth bounded space with tilted

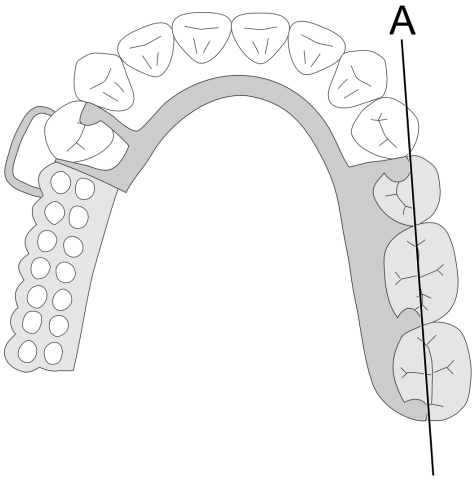

Figure 4. Schematic drawing of Kennedy Class II without modification or space restored with fixed prosthesis situation (RP8). It is a Category I, lateral type design with its insertion sequence from right to left. A, rotation axis.

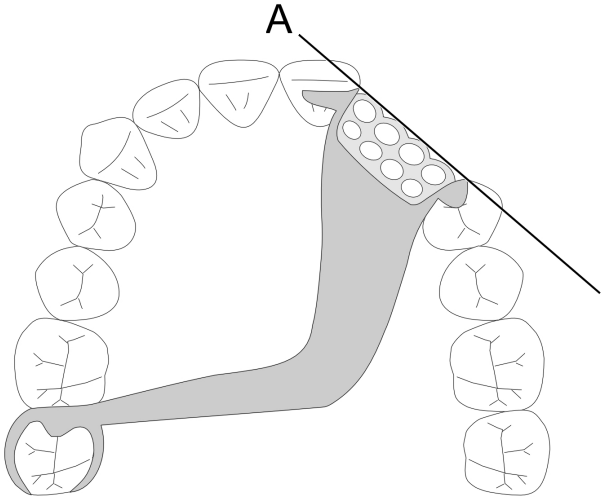

Figure 5. Schematic drawing of unilateral tooth bounded space with missing anterior and/or posterior teeth situation (RP5a). It is a Category II, diagonal type design with its rotation axis (A) on edentulous side and its insertion sequence from anterior-left to posterior-right.

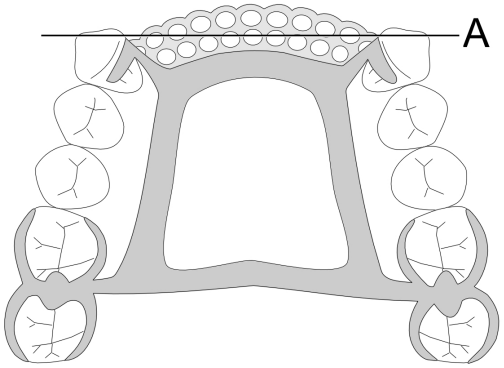

Figure 6. Schematic drawing of missing anterior teeth situation (RP1). A, rotation axis.

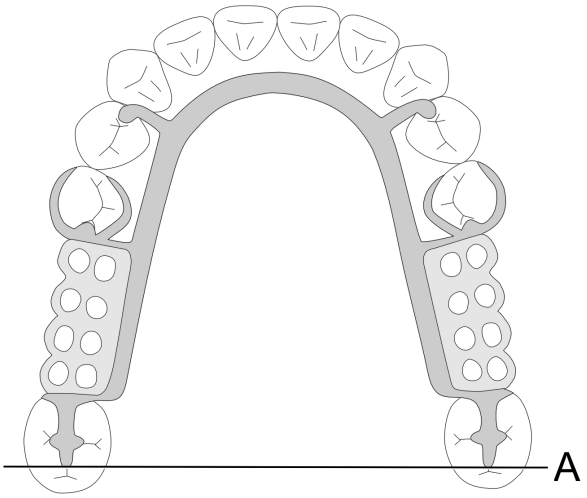

Figure 7. Schematic drawing of bilateral missing posterior teeth with tilted mandibular molars situation (RP2). A, rotation axis.

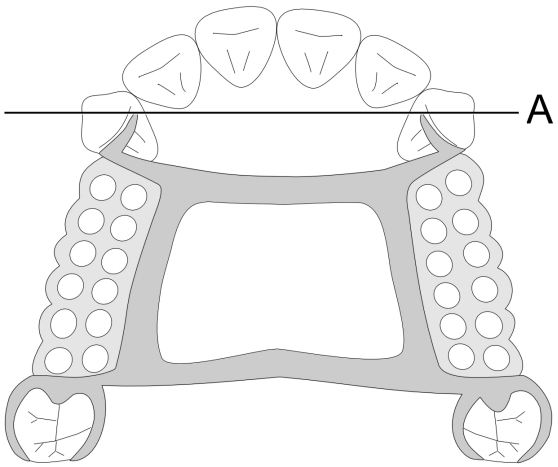

Figure 8. Schematic drawing of bilateral missing posterior teeth with aesthetic demands situation (RP3). A, rotation axis.

abutment (RP4, Fig 9)

This application type had only one report in 1997.[12] Ordinarily, a fixed prosthesis is the first choice to replace a single edentulous space. However, there remains a group of patients that, for medical, psychologic, and financial reasons, are poor candidates for fixed prosthodontics.[16] Bilateral removable partial denture for a small missing space is often rejected by patients, because the benefit to function does not balance the suffering to the foreign body sensation. A unilateral RPD design is often rejected by some dentists due to risk of accidental swallowing[38,39] and its poor retention and stability.[40] This unilateral rotational path design may overcome the problems of retention and stability and to reduce the chance of inhalation or swallowing the prosthesis. This unilateral design is modified from the original bilateral rotational path design (RP2). A bilateral design having two rotation centers on the two distal abutments on both sides. Therefore, the direction of the rotation axis is relatively fixed and can be adjusted in a limited range. On the other hand, a unilateral design has only one fixed rotation center, the other one is virtual in space and the rotation axis can be adjusted to a favorable direction to provide reasonable block-out, retention, and guiding plane.[12] So, the retention and stability can be controlled in this small prosthesis. The most suitable clinical condition for this rotational path application is missing mandibular first and second molars with mesially tilted third molar.

Unilateral tooth bounded space with missing anterior and/or posterior teeth (RP5)

This clinical situation has three design methods. The first method (RP5a, Fig 5) uses Category II design similar to RP1, but with lateral or diagonal insertion direction and sequence. [19,20,23] Anterior clasp is eliminated and replaced by rigid retainer and however, that of posterior abutment can be preserved or omitted.[14,41] One or two conventional direct retainers on contralateral side (dentate side) are the main retentive components of the whole denture, but for aesthetic reason, it is always placed on molar area,[19,20,23] so a diagonal insertion pattern is formed.[23]

The second method (RP5b, Fig 10) uses Category I rotational path described by Krol.[6,8] In his design, the rotation axis run between two buccal borders of long occlusal rests which are located at the middle of bucco-lingual dimension of occlusal surfaces of the anterior and posterior abutments of the edentulous ridge. Buccal clasps of anterior and posterior abutments are eliminated. Lingual or palatal undercuts or embrasures are engaged by lingual or palatal plates while denture is at its final position. The components buccal to the rotation axis such as the buccal flange and denture base of the edentulous area should be eliminated or relieved to avoid interference to the rotational path during insertion. Moreover, the design for the retentive clasp on dentate side is generally embrasure rest and clasp, which is unaesthetic if placing forward to premolar area, and always breaks occlusal integrity and easily broken.[32,42] A Category II design

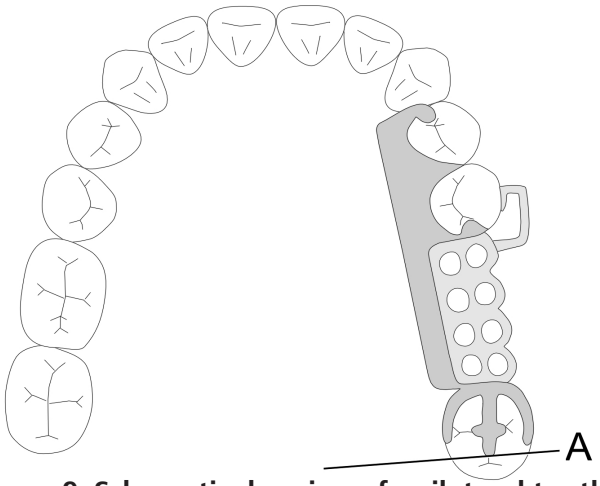

Figure 9. Schematic drawing of unilateral tooth bounded space with tilted abutment situation (RP4). A, rotation axis.

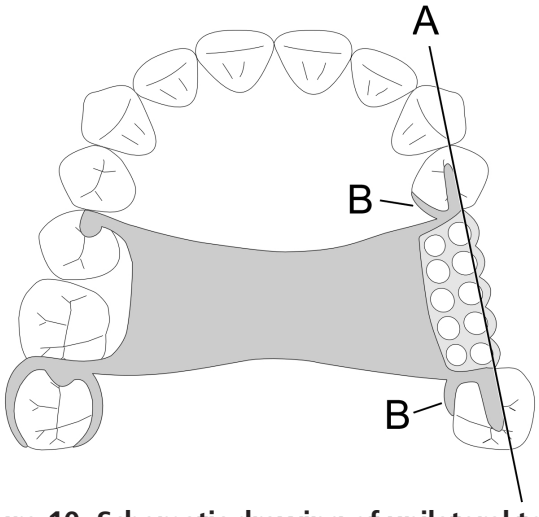

Figure 10. Schematic drawing of unilateral tooth bounded space with missing anterior and/or posterior teeth situation (RP5b). It is a Category I design with its rotation axis (A) on edentulous side. B, rigid retentive components.

(RP5a) seems to be better for this situation if buccal undercut of abutments of edentulous side are sufficient.

The third method (RP5c, Fig 11) described by Ring[10] and Baharav[21] is a Category I design with its rotation axis on the dentate side. It is like the design of Kennedy Class II without modification or space restored with fixed prosthesis (RP8) being discussed later. The purpose of this design is to solve the problem of tight occlusion on the dentate side and to avoid breaking occlusal integrity. By using a rotational path, the lingual or palatal plate, the rigid retentive component can be engaged to the lingual or palatal surface, or embrasure area. On the edentulous side, anterior clasp is eliminated due to aesthetic reason, so main retention is provided by a posterior retentive clasp.

Flaring anterior abutment, tooth bounded (RP6, Fig 12)

This application type was only reported in the textbook edited by Krol in his consecutive editions.[6,19,20,31] He described the curved path of insertion[31] in his second edition of the textbook in 1976 that it may be used when anterior teeth are flared labially and aesthetic clasping would be difficult. Curved path permits placement of clasps in the cervical area of the teeth. In the third and fourth editions,[6,19] he used the term of rotational path or dual path instead of curved path of insertion. And in the fifth edition, he described more to the design of the anterior clasp that a bar clasp is usually most effective.[20] It is an innovative idea that a conventional flexible direct retainer rather than a rigid retainer can be used in the rotational path design. However, there was no other publication describing this concept by other authors.

Flaring anterior abutment, distal extension (RP7, Fig 13)

Donovan[13] described a case report to use the rotational path concept in a Kennedy Class II patient. The design of this rotational path denture is Category II with an anterior to posterior diagonal insertion direction. The purpose of the application is for aesthetics because the labial clasp of the anterior abutment can be eliminated. The rigid retainer (a distal proximal plate) engaging to distal undercut of distal surface provides retention. Recently, a modification design was reported by Syu.[43] A flexible retentive clasp rather than a rigid retainer was designed on the anterior abutment and placed more cervically using the concept by Krol.[19,20,31] In the Kennedy Class II distal extension situation, denture stability is more important than aesthetics. The denture base on the distal extension edentulous ridge tends to move distally, therefore, the labial clasp on the distal abutment tooth is not only for retention, but for stability of the denture.

Kennedy Class II without modification or space restored with fixed prosthesis (RP8, Fig 4)

This application type is the earliest application reported in dental literature. It was first reported by Humphreys[17] in 1935, and has evolved over the years. Finally, the Hart-Dunn attachment was

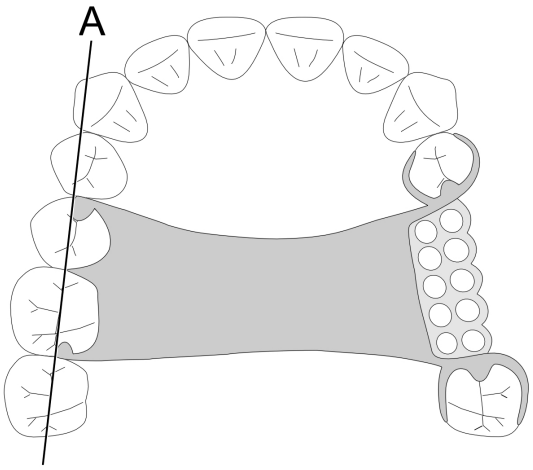

Figure 11. Schematic drawing of unilateral tooth bounded space with missing anterior and/or posterior teeth situation (RP5c). It is a Category I design with its rotation axis (A) on the dentate side.

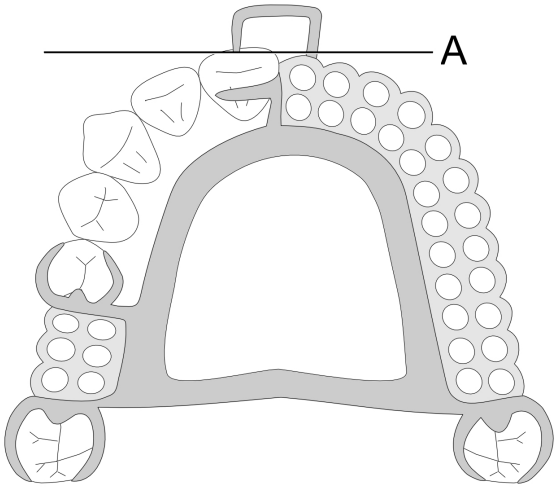

Figure 12. Schematic drawing of flaring anterior abutment, tooth bounded situation (RP6). A, rotation axis.

described by Mann[1] used embrasure clasping on the dentate side for the retention of unilateral distal extension partial dentures and proposed the concept of rotatory path. Although Garver[2] modified this design further in 1978, its use was limited, because it was specified for a Kennedy Class II situation with a fixed partial denture on the contralateral side. After rationale and principle of rotational path were developed and discussed in the following years,[3,5] specially designed fixed partial dentures on the contralateral side are not required, and the versatility of the application is increased. Some authors[10,21] used lingual or palatal minor connector to engage lingual or palatal undercut or sub-pontic undercut over the fixed prosthesis which restored the modification space of Kennedy Class II situation (RP8), and Kennedy Class III or IV situations (RP5c). When applying in Kennedy Class II situations, force control on the contralateral side is mandatory. Usually, the area of engagement is restricted and should be adjusted to avoid harmful force applied to the abutment during function on distal extension side. On the contrary, force control is not the major consideration in RP5 tooth bounded situations.

Kennedy Class II with modification, with tilted molar (RP9, Fig 14)

This application was described by Asher[11] in 1992. It is classified as Category I, with a diagonal insertion direction from the posterior of one side to the anterior of the other side. Biomechanical principles should be considered to avoid deleterious force on the mesial surface (usually mesio-lingual surface) of the posterior molar abutment on the tooth-bounded ridge by the rigid retentive retainer in application of rotational path to construct a removable partial denture for Kennedy Class II distal extension situation. This design is also applied in Kennedy Class II without modification. In a case report by Syu,[43] a rigid retainer was designed to engage mesio-lingual undercut of tilted molar on the dentate side.

In our study, nine application types were determined and may be applied in various clinical situations when indicated. According to different clinical situations, some modifications to the standard design were used for fulfilling different purposes.[12,25,43] The number of reports related to each type of clinical application is not positively correlated to the importance of that application type but represents that its clinical result is attractive and more easily shown in the literature. Missing anterior teeth is a representative example in the rotational path of insertion. In this application type, it is an effective improvement in aesthetics by relatively simple design. Therefore, it is so popular that discussion about RP1 was found in 76% of all included articles in our study. The frequency of the application of rotational path in removable partial denture design may be different in various districts or countries according to the patient's demographics, psychology, systemic and oral health,[44,45] medical supply ability, the ability, experience and preference of dental practitioner and technician.

The purposes of use of the rotational path of insertion are different in various types of application. Generally, in designing a removable partial denture, if the condition can be managed by conventional method, a rotational path is not considered. It is because the conventional method is more straight forward thinking and more easily communicates

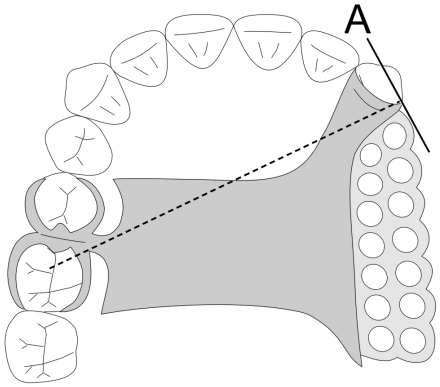

Figure 13. Schematic drawing of flaring anterior abutment, distal extension situation (RP7). A, rotation axis.

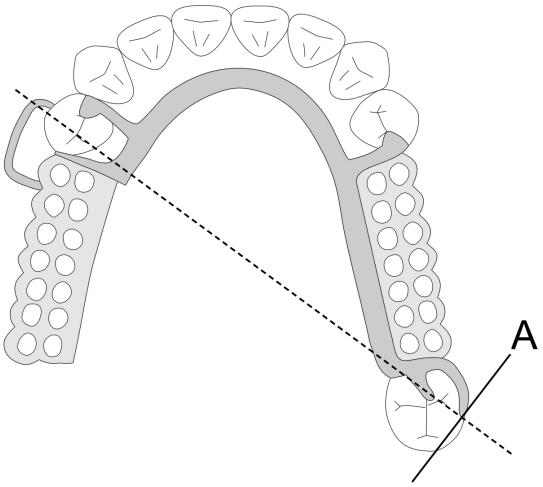

Figure 14. Schematic drawing of Kennedy Class II with modification, with tilted molar situation (RP9). A, rotation axis.

with the technicians and the result and the effect are more predictable. Therefore, the rotational path is only a supplemental tool to assist or to solve some problems encountered in conventional denture design. In the literature review, improving aesthetics and engagement of a difficult approaching undercut are the major reasons to apply rotational path of insertion.

Generally, if the rotational path is used in anterior portion, it is for aesthetic reason so that unsightly clasp may be eliminated. If it is used in the posterior area, aesthetic is less important, so it is for the engagement of difficult approaching undercuts. At last, if it is used in distal extension situations, it may provide aesthetics or retention. However, biomechanical principle should be considered in the design to avoid harmful force on the abutments engaged by rigid retentive components.

In our study, it was concluded that rotational path of insertion is a feasible technique and it is worth encouraging dental practitioners to utilize this technique in appropriate clinical situations. However, the clinical application types determined in our study were based on relative weak evidence (clinical descriptions and case reports). In the future, further studies are needed to evaluate the clinical performance and long-term outcome of this technique. In addition, the consideration for rotational path of insertion in computer-aided design (CAD) software should be evoked.

Conclusions

In the literature review, it was known that there were nine application types that rotational path of insertion can be applied in various situations including tooth bounded or distal extension, anterior or posterior, unilateral or bilateral conditions. In removable partial denture design, conventional path of insertion is in the first place to be considered. However, there are limitations in conventional design and the rotational path of insertion as a supplemental tool is to assist or to solve some problems in denture design. Biomechanical principles are the common factors considered in both the conventional and rotational path of insertion. Each type of application of rotational path has different clinical consideration and purposes to be accomplished, and so possesses different design and characteristics. Appropriate design by dental practitioners and precise laboratory works by well-trained technicians are the foundation of successful prosthesis.

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