Clinical outcomes of rigid and non-rigid telescopic double-crown-retained removable dental prostheses: An analytical review

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PURPOSE. The objective of this literature review was to analyze the cumulative survival rates (CSRs) of rigid and non-rigid double-crown-retained removable dental prostheses. **MATERIALS AND METHODS.** Screening of the literature published from January 1995 to December 2019 was performed by using electronic data base (Pubmed) and manual search. The CSRs of rigid and non-rigid double crown removable dental prostheses were investigated. **RESULTS.** A total of 403 articles were reviewed and 56 relevant articles of them were selected. Subsequently, 25 articles were included for data extraction. These articles were classified according to rigid and non-rigid type double crowns and further subdivided into teeth, implants, and teeth-implant combination types. The CSRs of rigid type double crown ranged from 68.9% to 95.1% of 5 to 10 years in tooth abutments, 94.02% to 100% over a 3-year mean observation periods in implant abutments, and 81.8% to 97.6% in tooth-implant combination. Non-rigid type double crowns had various CSR ranges from 34% to 94% maximum during 10 years observation in teeth abutment. The CSRs of non-rigid type had over 98% in implant abutments, and ranged from 85% to 100% in tooth-implant combination. **CONCLUSION.** The CSRs of double crowns varies according to types. With accurate evaluation of the remaining teeth and plan of the strategic implant placement, it could be successful treatment alternatives for partially or completely edentulous patients. ***[J Adv Prosthodont 2020;12:38-48]***

KEYWORDS: Telescopic double crown; Rigid double crown; Non-rigid telescopic crown; Cumulative survival rate; Clearance fit

INTRODUCTION

For the successful treatment of a removable partial denture (RPD), several factors, such as the occlusion of the denture, an impression for appropriate support in the edentulous area, and a retention element to prevent denture dislodgment, need to be considered. When considering the retention element, it can be classified into clasp-retained RPDs or double-crown-retained RPDs according to its mechanism. In patients with few residual teeth, designing clasp-retained RPD is often inadequate and difficult for clinicians.[1] Various factors should be considered for the prosthetic restoration of these patients, particularly the prosthetic restoration preferences and economic aspects. In addition, clinicians should consider the number and locations of residual teeth, extraction, strategic implant placement, and type of opposite dentition according to the available prosthetic options. In such cases, double-crown-retained RPDs can be a successful treatment alternative for patients with few remaining teeth. Double-crown RPDs are characterized by the presence of fixed and removable restorations in hybrid form. The inner crown (primary crown) is the fixed restorations in the oral cavity, either in the form of crown of abutment teeth, or abutment of the implant. In contrast, an outer crown (secondary crown) is fabricated as a removable component in a RPD.[2]

Double-crown-retained RPDs can be classified as conical, telescopic, or hybrid telescopic crowns according to the mechanism ensuring retention of the inner crown.[3] The conical double crown was first introduced by Köber in 1968.[4] An inner crown made of precious metal has a slope

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of 6° and includes a mechanism for exerting 5 - 10 N of retention force from the end position via a wedge action between the inner and outer crowns.[3] The telescopic double crown was first introduced by Böttеger in 1970 and includes a mechanism for exerting retentive force via friction generated between a noble metal crown with a 0° taper parallel to the end position of the noble metal inner crown.[5] In noble metal crowns in conical and telescopic double crowns, retention forces are reduced by wearing of the inner and outer crowns.[6] If the inner and outer crowns are made of non-precious metal, additional attachments (e.g., Marburg double crown system, or hybrid telescopic double crowns using additional friction pin) are needed to exert retention force with a definite end position, which is called a hybrid telescopic double crown.[7,8]

Telescopic double crowns also could be classified as either rigid or non-rigid according to the clearance fit.[9] Rigid double-crown-retained RPDs are defined as having no clearance fit between the inner and outer crowns. It uses friction or a wedging effect between the inner and outer crowns for exerting the retention forces and therefore does not allow vertical movement when loading is applied.[10] The rigid type includes frictional type double crowns, RPDs using galvanoformed (same as electroformed) secondary crowns, or conically prefabricated copings. By contrast, non-rigid double-crown-retained RPDs have clearance fit between the inner and outer crowns.[11]

Both precious and non-noble metals can belong to this type. If noble metal alloy inner and outer crowns are fabricated with the clearance fit, it can be the non-rigid double crown. In non-precious metal alloys, the oxide slag of the cast inner crown is removed after a polishing procedure, resulting in minor dimensional changes of the fit between the inner and outer crowns.[8] Hence, no retentive force exists between them and an additional retention attachment is needed, such as the Marburg double crown and hybrid telescopic double crown with a friction pin. The Marburg double-crown-retained RPD has 0.3 - 0.5 mm of clearance fit on the occlusal surface and an additional attachment called the TK-SNAP (Si-tec, GmbH, Herdecke, Germany) for retention.[11] Furthermore, a hybrid telescopic crown with a friction pin has a retention pin fabricated through spark erosion between the inner and outer crowns.[8] When functional loading is applied to the denture, the non-rigid type allows additional vertical movement by the clearance fit and distributes the force to the edentulous ridge.[10]

Recently, several review articles have reported that double-crown-retained dentures led to the successful clinical outcomes. In a systematic review reported by Koller *et al.*, the cumulative survival rate of the abutment in seven studies was 68% - 95.3% during 4 to 10 years of follow-up and the implant survival rates in three studies was 97% - 100%.[10] According to Verma et al., the survival rate of abutment teeth during a 6-year observation period was 96.5%, and the survival rate of implants was 97.9% - 100% and 100% for telescopic-retained removable dental prostheses with two mandibular implants after 10.4 years.[12] However, many previous studies have not clearly defined rigid and non-rigid type, and little is known about the survival rates of abutments according to this classification. Therefore, the objective of this article review was to investigate the cumulative survival rates of abutments in rigid and non-rigid double-crown-retained RPDs.

MATERIALS AND METHODS

i. Search strategy

A PubMed search was conducted for identifying articles published in the dental literature from January 1995 to December 2019 using the following search terms as shown below:

"telescopic crown", "telescopic double crown", "rigid telescopic crown", "resilient telescopic crown", "non rigid telescopic crown", "Marburg double crown", "implant supported double crown", and "tooth supported double crown". The bibliographies of all full-text articles and related reviews selected from the electronic search were also screened. Table 1 lists the journals that were manually searched.

1) Inclusion criteria

Articles published in English with randomized clinical trials (RCTs), prospective and retrospective cohort studies of double-crown RPDs were included. The specific inclusion criteria were as follows:

① Studies on double-crown RPDs supported by teeth, implants, or combination of teeth-implants
② Human clinical studies with at least 10 patients in each group
③ Studies with clinical examinations performed at the follow-up visits
④ At least 3 years of mean observation period
⑤ Studies that presented the information about the rigid and non-rigid types
⑥ Studies that reported cumulative survival rates of abutments

Table 1. Journal list of manual searching

Journal list
Journal of Dentistry
Clinical Oral Implants Research
Journal of Prosthodontics
Clinical Oral Investigation
Journal of Prosthetic Dentistry
Journal of Advanced Prosthodontics
International Journal of Prosthodontics
Clinical Implant Dentistry and Related Research
European Journal of Prosthodontics and Restorative Dentistry
International Journal of Oral and Maxillofacial Implants
International Journal of Periodontics and Restorative Dentistry

2) Exclusion criteria
① *In vitro* studies
② Studies about questionnaires, records, reviews, clinical reports, case series, surveys, and interviews
③ Multiple studies with identical patient groups
④ Studies on zygomatic implants, transmandibular implants, and blade vent implant systems

ii. Definitions

1) Rigid double-crown-retained RPDs

Rigid double-crown-retained RPDs are defined as those with no clearance fit between inner and outer crowns. The RPDs use friction or a wedging effect between crowns for exerting retentive forces. These included conically prefabricated copings with wedging effect, frictional telescopic crown, and galvanoformed (electroformed) secondary crowns (Fig. 1).

2) Non-rigid double-crown-retained RPDs

Non-rigid types have a clearance fit between the inner and outer crowns at the terminal position of denture. There is no retentive force between crowns due to the clearance fit. An additional attachment for retention is needed, including the TK-SNAP in Marburg double crown and friction pin in hybrid telescopic crown (Fig. 2).

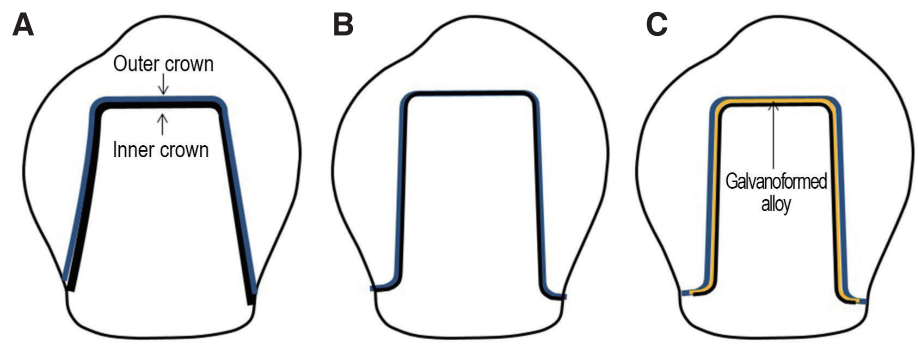

Fig. 1. Schematic diagrams of a rigid type double crown system. (A) Conical double crown with wedging effect, (B) Telescopic double crown with friction fit, (C) Galvanoformed (electroformed) double crown.

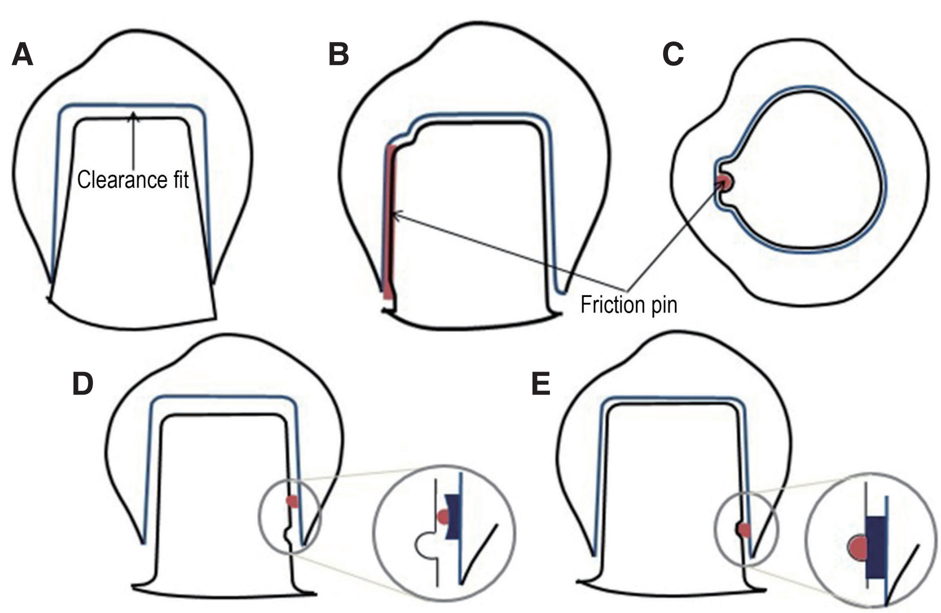

Fig. 2. Schematic diagrams of a non-rigid type double crown system. (A) Telescopic double crown with clearance fit, (B) Hybrid telescopic double crown with friction pin (cross sectional view), (C) Hybrid telescopic double crown with friction pin (occlusal view), (D) Marburg double crown and TK-SNAP (during insertion), (E) Marburg double crown and TK-SNAP (terminal position).

3) Survival

Survival of tooth and implant was defined as the reconstruction remaining in situ at the follow-up examination visit irrespective of its condition. Denture survival was defined as a condition that can be repaired by minor complications such as denture base fracture, artificial tooth fracture, and relining.

(Failure of dentures is defined as a condition that requires remake due to fracture of denture frame work, extraction of all abutment teeth, etc.)

iii. Data extraction

The outcome variables included the survival data of telescopic double-crown-retained RPDs, abutment teeth, and/or implants.

The following data were extracted:

1) Study information: authors, years of study, study design. number of patients, mean observation period
2) Types of double crown: rigid and non-rigid double crowns according to the definitions
3) Details of abutments: number of teeth and implants, CSRs of abutments and dentures

RESULTS

Of the 403 studies identified in the search, two reviewers (Cho and Seo) selected 56 articles for full-text review based on the information given in the abstracts (Fig. 3). From these 56 articles, 25 were chosen for data extraction with 12 studies derived from the PubMed search and 2 studies derived from the manual search (Table 2). The included papers were grouped according to the types of double crown, and each type was subdivided into tooth, implant, or tooth-implant combination support (Table 3). Excluded articles were excluded for the reasons listed below (Table 4).

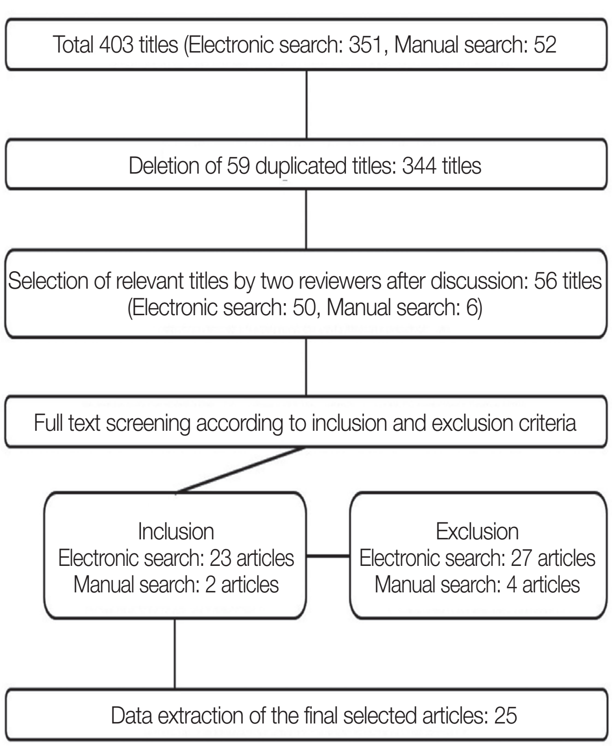

Fig. 3. Search strategy and results.

Table 2. Results of the literature search

Database	Number of relevant articles	Included studies	Excluded studies
PubMed	50	23	27
		Wenz *et al.*[13]	Koller *et al.*[10]
		Frisch *et al.*[14]	Wenz *et al.*[11]
		Frisch *et al.*[15]	Verma *et al.*[12]
		Frisch *et al.*[16]	Schwindling *et al.*[38]
		Krennmair *et al.*[17]	Eitner *et al.*[39]
		Krennmair *et al.*[18]	Behr *et al.*[40]
		Krennmair *et al.*[19]	Rammelsberg *et al.*[41]
		Rinke *et al.*[20]	Krennmair *et al.*[42]
		Rinke *et al.*[21]	Marotti *et al.*[43]
		Rinke *et al.*[22]	Stober *et al.*[44]
		Wöstmann *et al.*[23]	Szentpétery *et al.*[45]
		Szentpétery *et al.*[24]	Lian *et al.*[46]
		Zou *et al.*[25]	Bernhart *et al.*[47]
		Zou *et al.*[26]	Heckmann *et al.*[48]
		Zou *et al.*[27]	Kaufmann *et al.*[49]
		Guarnieri *et al.*[28]	Dittmann *et al.*[50]
		Kern *et al.*[29]	Mengel *et al.*[51]
		Stober *et al.*[30]	Schwarz *et al.*[52]
		Weigl *et al.*[31]	Rehmann *et al.*[53]
		Zierden *et al.*[32]	Weng *et al.*[54]
		Fobbe *et al.*[33]	Brandt *et al.*[55]
		Mengel *et al.*[34]	Keshk *et al.*[56]
		Widbom *et al.*[35]	Behr *et al.*[57]
			Schwindling *et al.*[58]
			Brandt *et al.*[59]
			Eisenburger *et al.*[60]
			Coca *et al.*[61]
Manual Search	6	2	4
		Romanos *et al.*[36]	Saito *et al.*[62]
		Romanos *et al.*[37]	Bergman *et al.*[63]
			Joda[64]
			Weischer *et al.*[65]

Table 3. Classification of included articles

Type (Number)	Tooth only group	Implant only group	Tooth-implant combination group
Rigid (15)	Wöstmann *et al*.[23]	Zou *et al*.[25]	Guarnieri *et al*.[28]
	Szentpétery *et al*.[24]	Zou *et al*.[26]	Kern *et al*.[29]
	Stober *et al*.[30]	Zou *et al*.[27]	Fobbe *et al*.[33]
	Zierden *et al*.[32]	Krennmair *et al*.[17]	Romanos *et al*.[36]
		Rinke *et al*.[21]	
		Weigl *et al*.[31]	
		Romanos *et al*.[37]	
Non-rigid (10)	Wenz *et al*.[13]	Frisch *et al*.[14]	Frisch *et al*.[16]
	Rinke *et al*. [22]	Frisch *et al*.[15]	Rinke *et al*.[20]
	Widbom *et al*.[35]	Krennmair *et al*.[18]	Krennmair *et al*.[19]
			Mengel *et al*.[34]

Table 4. Reasons for exclusion

Reasons	Exclusion articles	Reasons	Exclusion articles
No cumulative survival rates of abutments loss	Wenz *et al*.[11]	Same patient group included	Stober *et al*.[44]
	Schwindling *et al*.[38]		(Same as Stober *et al*.[30])
	Behr *et al*. [40]		Szentpétery *et al*.[45]
	Heckmann *et al*.[48]		(Same as Szentpétery *et al*.[24])
	Kaufmann *et al*.[49]		
	Brandt *et al*.[55]	Systematic review	Koller *et al*.[10]
	Behr *et al*.[57]		Verma *et al*.[12]
	Schwindling *et al*.[58]		Lian *et al*. [46]
	Brandt *et al*.[59]		Keshk *et al*.[56]
	Bergman *et al*.[63]		
		Under 3 years of mean observation period	Bernhart *et al*.[47]
No information for classification of telescopic crown	Eitner *et al*.[39]		Weng *et al*.[54]
	Rehmann *et al*.[53]		Joda[64]
	Eisenburger *et al*.[60]		
	Saito *et al*.[62]	Less than 10 patients in control group	Mengel *et al*.[51]
	Coca *et al*.[61]		
	Weischer *et al*.[65]		
		No seperation of CSR data according to classification	Dittmann *et al*.[50]
Same patient group included	Rammelsberg *et al*. [41]		
	(Same as Fobbe *et al*.[33])		
	Schwarz *et al*.[52]	Other attachment used	Marotti *et al*.[43]
	(Same as Fobbe *et al*.[33])		
	Krennmair *et al*.[42]		
	(Same as Krennmair *et al*.[18])		

1) Rigid type, tooth supported double crowns

Total 4 articles were included as shown below (Table 5). The RCTs, performed by Stober *et al*.,[30] reported CSRs (6-year observation period) of the prostheses supported by either electroplated (EP-RPDs) or cast double crowns (C-RPDs). The CSRs of abutment were 85% for EP-RPDs and 91% for C-RPDs, and those of dentures were 77% and 97%, respectively. Overall CSRs of teeth and dentures were reported 88% and 87%.

The three retrospective studies were reported. Wöstmann

Table 5. Studies of rigid type with tooth supported double crowns

Study	Study design	Mean observation period (year)	No. of patients	No. of teeth	No. of dentures (Types of dentures)	Cumulative survival rate (%)	
						Tooth	RPD‡
Stober *et al.*[30]	RCT*	6	54	217	60 (Electroplated, or cast telescopic crown)	88	87
Wöstmann *et al.*[23]	RS†	5.3	463	1758	554 (Cast telescopic crown)	95.1 (At 5 year)	95.3 (At 5 year)
Szentpétery *et al.*[24]	RS†	5	74	173	82 (Telescopic crown)	90.4	.
Zierden *et al.*[32]	RS†	3.87	462	1946	572 (Precious and non-precious alloy telescopic crown)	92.0 (At 5 year) 68.9 (At 10 year)	96.1 (At 5 year) 84 (At 10 year)

RCT*: randomized clinical trial, RS†: retrospective study, RPD‡: removable partial denture

Table 6. Studies of rigid type with implant supported double crowns

Study	Study design	Mean observation period (year)	No. of patients	No. of implants	Implant system	No. of dentures (Types of denture)	Cumulative survival rate (%)	
							Implant	RPD‡
Krennmair *et al.*[17]	PS*	3	25	100	Camlog	25 (Gold alloy cast, telescopic crown)	100	100
Rinke *et al.*[21]	RS†	5.9	14	86	Ankylos	18 (Galvanoforming, telescopic crown)	98.8	100
Zou *et al.*[25]	RS†	6.05[a]	20	106	ITI	20 (Electroformed, telescopic crown)	100	100
Zou *et al.*[26]	PS*	3	10	40	ITI	10 (Electroformed, telescopic crown)	100	100
Zou *et al.*[27]	RS†	5	24	88	ITI	24 (Electroformed, or non-precious telescopic crown)	100	.
Weigl *et al.*[31]	PS*	3	20	91	Ankylos	21 (Electroplate, cast and prefabricated crowns)	98.91	.
Romanos *et al.*[37]	RS†	4.54	26	117	Ankylos	26 (Conically prefabricated crown)	94.02	.

PS*: prospective study, RS†: retrospective study, RPD‡: removable partial denture, a: mean observation period was calculated from the article

et al.[23] reported CSRs of abutment as 95.3%, and denture as 95.1% after 5-year observation period according to the Kaplan-Meier survival curve. Szenpètery *et al.*[24] assessed 74 patients (mean age, 66 years) with frictional telescopic crowns, and the CSR was 90.4% after 5 years of follow-up. Zierden *et al.*[32] has reported that 5-year CSRs of tooth and denture were 92.0% and 96.1%, and 10-year of those were 68.9% and 84% each.

2) Rigid type, implant supported double crowns

Seven papers were selected (Table 6), three of which were prospective studies and the others were retrospective studies. In prospective studies, Zou *et al.*[26] reported 100 % of CSR for 3 years in the group treated with four implants per patient and electroformed double crown, and Weigl *et al.*[31] and Krennmair *et al.*[17] also reported 98.91% and 100% of CSR for 3 years, respectively. In four retrospective studies, Rinke *et al.*[20] and Romanos *et al.*[37] studies showed CSR of 98.8% and 94.02%, respectively. The remaining two studies showed a high overall score of 100% regardless of the mean observation period.

3) Rigid type, tooth-implant combination double crowns

Total four studies were involved (Table 7). Guarnieri and Ippoliti[28] reported that CSRs of tooth was 91.8% and that of implant was 96.4%. Kern *et al.*[29] also performed prospective studies that the CSRs were 81.8% for tooth, and 97.6% for implant with 11.3 years mean observation period. Fobbe *et al.* presented that CSR of tooth and implant was 97.2%, 96% for 5 years, respectively. Romanos *et al.*[36] involved the immediate loading of mandibular telescopic RPDs, and the CSRs of tooth and implant were reported 88% and 97.27%.

4) Non-rigid type, tooth supported double crowns

Three retrospective studies were included (Table 8). Wenz *et al.*[13] treated with Marburg double-crown-retained RPDs; the CSR was 94% after 5 years and 82% after 10 years, and that of RPDs was 100%. Rinke *et al.* reported relatively low CSR of tooth and RPDs on less than four abutments of telescopic crowns. The CSR of tooth and RPD was 55% and 62% after 5 year, 34% and 38% after 8 years. Widbom *et al.* reported that the CSR of tooth was 93% with snap attachment called Ipso-clip system (Ipso-clip, Cendres et Métaux).

5) Non-rigid type, implant supported double crowns

One prospective study and two retrospective studies were searched (Table 9). These three studies all used Marburg systems. Frisch *et al.*[14] the CSR of implant recoreded 98.9% in 14.1 years. In another study by the same author, the CSR was 98.75% during the mean observation period of 5.64 years. A prospective study of Krennmair *et al.*[18] showed 100% of CSR in two mandibular interforaminal implants treatment with double-crown-retained prostheses.

6) Non-rigid tooth-implant combination telescopic double crowns

A total of four studies were included and all studies used Marburg double crown system (Table 10). Frisch *et al.*[16] reported the CSR of tooth was 86.36%, and those of implant and RPD were 98.63% and 100%, respectively. Rinke *et al.*[21] reported that the CSR of tooth was 85.19% and that of both implant and RPD was 100% during 5.84 years mean observation period. In a study by Krennmair *et al.*[19], the CSRs of tooth and implant were both 100%. In a study by Mengel *et al.*[51], the CSR was reported 100% for both tooth and implant.

Table 7. Studies of rigid type, tooth-implant combination double crowns

Study	Study design	Mean observation period (year)	No. of patients	No. of teeth / implants	Implant system	No. of dentures (Types of denture)	Cumulative survival rate (%)		
							Tooth	Implant	RPD‡
Guarnieri *et al.*[28]	RS†	15	18	233 / 164	BioLok	36 (Co-Cr alloy, telescopic crown)	91.8	96.4	100
Kern *et al.*[29]	PS*	11.3	31	66 / 84	Bonefit dental implant	33 (Gold alloy, telescopic crown)	81.8	97.6	91.0
Fobbe *et al.*[33]	RS†	4.2	126	239 / 412	.	139 (Galvanoforming, telescopic crown)	97.2 (At 5 year) 80.4 (At 10 year)	96 (At 5 year) 88.5 (At 10 year)	.
Romanos *et al.*[36]	RS†	5.13	55	75 / 110	Ankylos	55 (Conically prefabricated crown)	88	97.27	100

PS*: prospective study, RS†: retrospective study, RPD‡: removable partial denture

Table 8. Studies of non-rigid type, tooth supported double crowns

Study	Study design	Mean observation period (year)	No. of patients	No. of teeth	No. of dentures (Types of denture)	Cumulative survival rate (%)	
						tooth	RPD†
Wenz *et al.*[13]	RS*	4.1	125	460	125 (Marburg double crown)	94 (At 5 year) 82 (At 10 year)	100 (At 5 year) 100 (At 5 year)
Rinke *et al.*[22]	RS*	5.38	221	538	263 (Marburg double crown)	55 (At 5 year) 34 (At 8 year)	62 (At 5 year) 38 (At 8 year)
Widbom *et al.*[35]	RS*	3.8	72	368	75 (Ipso-clip telescopic crown)	93	96.3

*RS: retrospective study, RPD†: removable partial denture

Table 9. Studies of non-rigid type, implant supported double crowns

Study	Study design	Mean observation period (year)	No. of patients	No. of implants	Implant system	No. of dentures (Types of denture)	Cumulative survival rate (%)	
							Implant	RPD‡
Frisch *et al.*[14]	RS*	14.1	22	89	Bränemark, Ankylos, Frialit2, ITI Bonefit, Biomet 3i, IMZ, Sigma	22 (Marburg double crown)	98.9	77.3
Frisch *et al.*[15]	RS*	5.64	20	80	Ankylos	20 (Marburg double crown)	98.75	100
Krennmair *et al.*[18]	PS†	5	12	24	Camlog	12 (Marburg double crown)	100	.

RS*: retrospective study, PS†: prospective study, RPD‡: removable partial denture

Table 10. Studies of non-rigid type, tooth-implant combination double crowns

Study	Study design	Mean observation period (year)	No. of patients	No. of teeth / implants	Implant system	No. of dentures (Types of denture)	Cumulative survival rate (%)		
							Tooth	Implant	RPD‡
Frisch *et al.*[16]	RS*	6.12	26	66 / 61	Ankylos	23 (Marburg double crown)	86.36	98.63	100
Rinke *et al.*[20]	RS*	5.84	18	27 / 24	Ankylos	14 (Marburg double crown)	85.19	100	100
Krenmair *et al.*[19]	RS*	3.17	22	48 / 60	Frialit2, Xive, Camlog root-line	22 (Marburg double crown)	100	100	.
Mengel *et al.*[34]	PS†	9.25[a]	16	. / 83	Osseotite	21 (Marburg double crown)	100	100	.

RS*: retrospective study, PS†: prospective study, RPD‡: removable partial denture, a: mean observation period was calculated from the article

DISCUSSION

When a clinician encounters a patient with only a few teeth in the arch, the double crown system can be an excellent treatment alternative, given the cost and technical difficulty. In this case, the prognosis of RPD can be successfully guided by assessing the number of teeth remaining, the distribution, the degree of periodontal support, and additional implant placement. Recent reports support that double-crown-retained RPDs have similar clinical performance compared to clasp-retained RPDs. According to Ishida *et al.*,[66] the CSR of double-crown-retained RPDs and clasp-retained RPDs for 5 years were 100% and 94.5%, respectively. The 5-year cumulative survival rate of abutment teeth was 96.8% in double-crown-retained RPDs and 91.5% in clasp-retained RPDs. Saito *et al.*[62] reported that the incidence of loss of abutment was 11.4% in telescopic crown dentures with an average wearing period of 8.1 years and 5.2% in ordinary clasp-retained dentures with an average wearing period 5.3 years.

The CSR of tooth tends to decrease over time in double-crown-retained RPDs, regardless of types. Study of Rinke *et al.*[22] recorded excessively low CSR of tooth in non-rigid type. The author suggested that non-rigid type itself has no beneficial effects on clinical performance comparing to rigid type, but the number of abutment has an effect on the CSR. Considering reporting of Rinke *et al.*,[22] the CSR of abutment is relatively low in both non-rigid and rigid types. This suggests that it is recommended to evaluate the number, distribution, and periodontal support of remaining teeth at the beginning of the treatment and to increase the CSR through additional implant placement. Regardless of the types, strategic implant placement should lead to a therapeutic approach to increase the survival rate of abutments and prostheses. This is in line with the result that the CSR of abutment in the tooth-implant combination is more than 80% in both types for maximal 10-year observation period. Higher CSR in the implant-only or tooth-implant combination, rather than the tooth-only form, does not mean that the implant itself is better for survival than natural teeth, but its additional placement has a positive effect on survival. Implants located at strategic positions additionally contribute to the distribution of occlusal forces applied to the alveolar bone and supporting tissue through the placement of the RPD. When the secondary splinting effect is applied to natural teeth and implants in double crown dentures, osseointegrated implants can distribute stress to the surrounding cortical region.[67-69] Hence, stress around abutment teeth and their supportive tissue is reduced so that the implants in tooth and tooth-implant combination double-crown-retained RPDs can protect the teeth and their periodontal support tissues by relieving functional loading during mastication.[70]

These are closely related to complications that affect the survival and success of abutments and implants. A number of articles reported that the main factors affecting abutment tooth loss have also biological and technical complications (progression of periodontal disease, secondary caries and tooth fractures, etc.).[12] Widbom *et al.*[35] reported that the most common complication was cement loss and abutment tooth fracture (only 10% of abutment teeth had caries and 20% had a periodontal pocket depth of over 4 mm). Stober *et al.* reported that the risk of failure was higher for non-vital teeth than for vital teeth.[30] Technical complications also occurred frequently in the following order: decementation of primary crowns (37% in Mock *et al.*[71], 34.2% in Schwindling *et al.*[38]), failure of the veneer of secondary crowns (26.9% in Wöstmann *et al.*[23] 11.1% in Schwindling *et al.*[38]), fracture of denture base, and need for relining.

Decementation more frequently occurs in rigid type double crown RPDs. Behr *et al.*[40] reported the frequency of decementation according to the type of double crown RPDs (frictional fit, conical fit and clearance fit). After 10 years of observation, decementation occurred in 32% of friction fit and 53.2% of conical fit, whereas it occurred in 21.3% of the clearance fit. Retentive forces from the rigid type largely depend on mechanical factors such as length and taper of the crown. In addition to that, ductility and malleability of the noble metal alloy makes retention force adjustment be difficult. Excessive retentive force is often needed just after denture delivery. However, non-rigid type uses an additional attachment, allowing control of retentive force.

Complications that affect the CSR of implant are mainly categorized as biologic and mechanical factors. Factors affecting implant loss have also been suggested to be biologic complications such as peri-mucositis and peri-implantitis, which are related to the perio-parameters such as bleeding on probing and the modified Quigley-Hein Index. In a systematic review by Lian *et al.*,[46] the estimated incidences of mucositis and peri-implantitis were reported 5.89/100 implants/year and 0.12/100 implants/year, respectively. They lead to the marginal bone loss of implants ranged from 1.33 mm to 1.62 mm. Most studies on implant double-crown-retained dentures have reported that the main technical complications are loosening and fracture of primary abutment screws.[14,15,17,18,20] For maintenance, screw retightening or replacement of abutment could be performed. It is similar to re-cementation of primary crown of tooth abutment.

In this review, failure rates or abutments per year could not be calculated because of the lack of detailed information provided in the original articles. The Marburg double crown system was mainly included in non-rigid telescopic double crowns, and data about other attachment system were insufficient. Various follow-up studies are needed for non-rigid systems with different types of attachment. In addition, it is necessary to increase the homogeneity of the included literature so that quantitative analysis of clinical outcomes can be achieved through well-designed studies.

CONCLUSION

The CSR of double crowns varies according to the rigid, or non-rigid type. Regardless of its types, the CSRs of tooth supported groups were low and decreased over time. In implant supported double crowns, CSRs were reported above 94% for both rigid and non-rigid types. For both rigid and non-rigid types, CSRs of tooth-implant combination double crowns ranged over 80% in both teeth and implants. Subsequent studies should increase the homogeneity of articles to enable quantitative statistical analysis of cumulative survival rates.

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