Telescopic denture load distribution based on the telescopic crown design and material

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ABSTRACT
Retentive force (RF) on the telescopic crown (TC) retainer will be distributed to the abutment teeth. The optimal load distribution measured by RF on the abutment is 5-9 N. If the force is applied excessively, it will damage the tooth's supporting tissue, causing periapical lesions, bone resorption, and mobility. However, if the RF is minimal, the denture will not retentive. This paper will go through how RF will vary based on the chosen design and material. The cylindrical, conical, and resilient TC design are affected by the taper angle and the distance between the primary crown (PC) and secondary crown (SC). Resilience design can be modified by Marburg, Hofmann, and Yalisove. To create the precise taper angle and space in telescopic dentures (TD), CAD/CAM can now be used for the manufacture of TD using metal and non-metal materials. It is concluded that cylindrical TC design is rarely used because it is difficult to get tight contact between PC and SC, therefore conus or resilience design is more recommended. The smaller the taper angle, the greater the RF, but this depends on the material used. While the space between PC and SC, which is less than 50 μm, can also affect RF.
Keywords: telescopic denture, load distribution, telescopic crown design, telescopic crown material

INTRODUCTION

Treatment in edentulous patients varies in part depending on the patient's local and systemic factors. Local considerations include the quantity and position of missing teeth, occlusal relationships, the periodontal health of the remaining teeth, and the size or motion of the tongue.[1,2] The periodontal support of the support teeth and the design of the removable denture are two of the crucial elements in the planning of removable denture designs that are related to the distribution of loads to dental and mucosal supports. Once the denture is removed, a resultant force is applied to the supporting teeth along the lateral and vertical axes, and the periodontal support of the tooth must be strong enough to withstand this force.[1]

Removable denture design is one of the important factors in increasing long-term success and patient acceptance. The possibility of local soft tissue irritation or patient complaints can be caused by *unphysiologic* components in the form of major and minor connectors, functional extended border, and parts of the tissue teeth that cover the gingival margins of the support teeth.[3]

The ultimate tensile strength, which ranges 0.33-6.82 MPa, is the amount of force necessary to remove teeth from the socket.[4,5] According to Stantic et al, the force applied to each support tooth should be 5-9 N. Excessive force might harm the tooth's supporting tissue, leading to periapical lesions, bone resorption, and movement. However, removing prosthesis become easy if the RF is small.[5,6]

Retentive force on PC and SC when removing dentures will increase tensile stress on the support teeth. Strains that concentrate on the periodontal ligament and the apical region of the pulp tissue will cause periapical lesions. Meanwhile, if the strain concentrates on the bone and tensile stress on the periodontal tissue, it will cause resorption in the cervical area and increase the shaking of the support teeth.[5]

The TC outperformed other direct retainers in terms of effectiveness. This type of retention can be planned to adapt to the situation of the support gear by modifying the design of the telescope. The number of friction surfaces depends on the configuration of the taper angle and the space between PC and SC.[7] The design of a TC is generally classified into three types based on the retention mechanism: cylindrical, conus/conical, and resilient/clearance fit. Resilient design can be modified into Marburg design, Hofmann and Ludwig design, and Yalisove design. To get an accurate taper angle and space on the TD, CAD/CAM can be used with metal (CoCr) and nonmetal (Zirconia, PEEK).

This paper aims to discuss how RF will differ based on the design and material of the TC used. The design of the telescopic crown in the forms of cylindrical, conus, and resilient is influenced by the taper angle and space between the PC and SC. Various designs will result in different RF, so the dentist must be aware of this and modify the TC's design in accordance with the state of the supporting teeth.

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LITERATURE REVIEW

Telescopic denture/double crown system

A telescopic denture (TD) consists of a primary crown (PC) that is cemented into the support teeth and a precisely fitted secondary crown (SC). The PC must be at least 4 mm. Telescopic dentures, except clearance fit design, provide all the necessary functions of retentive elements such as retention, guidance, support and protection from movement. The double crown system distributes the load along the tooth axis so as to maintain the integrity of the periodontal ligament tissue and protect the tooth from dislodging movement of the removable denture. If the load is too great, it may result in issues such as periodontal damage, mucosal irritation, and patient pain.[1,2,8] Telescopic retainers offer treatments that can enhance natural maintenance and provide additional options for rehabilitating complex cases.[9]

The telescopic RPD was chosen because it produces support for teeth and soft tissues, has good retentive and superstructural qualities, a rigid splinting action, distributes loads effectively, and PC stabilizes dentures with mucosal support.[9] The advantages of the TD technique are excellent 3-dimensional immobilization of the restoration, defined release force, flexibility of design, and optimal access for oral hygiene. A PC with good adaptation can protect the support teeth from thermal irritation. In comparison to conventional RPD with clasp, the use of TD as a retentive element produces a better appearance, and TD can be repaired even if the supporting tooth is lost. [3,10]

The disadvantages of TD include a complex clinical and laboratory approach, which demands more treatment time and raises expenses. It is also difficult and challenging to achieve the ideal retention between PC and SC. Due to wear between the crown materials after TD use, the RF between the crowns may decrease. In order to provide space for PC and SC during the restoration of the support teeth, a significant amount of tooth material must be removed, which increases the risk of dental pulp morbidity, particularly in young patients. In TD, follow-up, regular review, and maintenance are required.[3,10]

The use of a telescopic denture is indicated when there are few and unevenly spaced support teeth, when those teeth need to be covered with a crown due to significant caries and poor contours, when those teeth have a questionable prognosis, when periodontitis has advanced, when it is challenging to determine the direction of the tide in the case of non-parallel support teeth, when someone has oral cancer, when natural teeth need to be connected to implants, when performing occlusal reconstruction and in patients with poor manual dexterity.[11]

According to the retention mechanism, the three types of telescopic crown designs are generally cylindrical, conus/conical, and resilient/clearance fit (Fig.1).

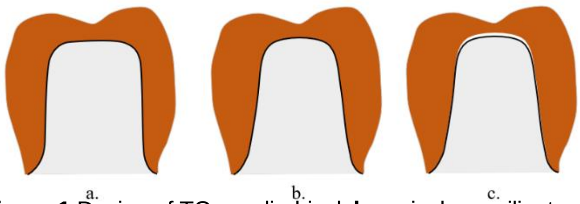

Figure 1 Design of TC; **a** cylindrical, **b** conical, **c** resilient

Cylindrical telescopic crown

The cylindrical crown's parallel surface (0°) produces a piston-cylinder effect that aids in gaining retention through frictional forces.[1] A cylindrical crown can only be used on teeth with good support tissue where it requires large retention. However, nowadays it is rarely used because retention is obtained from tight contact, so it is now more advisable to design a conus crown.[5,11]

The benefits of a cylindrical crown are its ability to alter retention force, good and stable RF over time, the ability to support teeth by acting as a splint, the ability to preserve periodontal tissue, and good removable denture retention. However, the limitations include the possibility of visible metal on the cervix, large RF on the support teeth when the GT is removed, the need for spacious vertical and buccal spaces, the potential need for endodontic treatment, easy insertion, and the need for a precise and accurate fit between the PC and SC during manufacturing. [1,11]

Conical or conus telescopic crown

It was first described by Korber in 1958 and provided friction only when completely seated produduced a *wedging effect* that created a large resistance force surface and increased RF.[1,6] A good tapered conus crown design can facilitate the installation and removal time of the TC without providing excessive friction that can affect the supporting tissue of the tooth. The smaller the taper angle conus crown, the larger the RF will be. The incline of the PC depends on the height of the clinical crown and the mobility of the periodontal. The number and location of the support teeth are also factors influencing the design of the taper and the total RF is calculated based on the number.[1,6,9,11]

Conus crowns are more commonly used over cylindrical crowns because they are easier to fa-

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bricate and do not significantly damage the tissues supporting the support teeth, but retention will decrease over time.[11] Because of its rigidity, the conus crown removable denture is not recommended for teeth with periodontal disease or questionable soft tissue conditions. When the removable denture retention is lost due to conus crown wear, polishing the occlusal surface of the PC with a silicone polishing disc can enhance the wedging effect so as to increase RF.[1]

The conus crown has the advantage, which is that it can adjust the RF to the condition of the support teeth. The retention force is stable over a long period of time, provides the effect of splinting the support teeth, maintains the periodontal tissue well and is aesthetically pleasing. However, the disadvantage is that sometimes there is an overconture appearance, the possibility of visible metal on the cervix, requiring root canal treatment if needed, when the support tooth is removed, the retention of the removable denture is doubtful, and it is a rigid connection.[1,11]

Resilience or clearance fit telescopic crown

Due to the flexibility in vertical and rotational movements, this type of design is referred to as a non-rigid design.[11] There is no friction or wedging when inserting or removing the removable denture. Retention is obtained from modifying the PC and SC or by adding attachments or functional molded denture borders and in contrast to other telescope systems, they can be used to maintain the removable denture with dental and/or mucosal support. This modification will reduce the tight contact between the PC and the SC and create a space between the PC and the SC.[1,2,11,12] In order to achieve optimum soft tissue support, the space between PC and SC allows for deformation and denture displacement toward the mucosa due to occlusal functional load.[1,13] This design also allows for the presence of resilience between the dentures and the support teeth, which can prevent harmful effects, harmonize with tissue elasticity, result in better distribution forces, and increase the survival rates of abutments. Resilience design provides advantages in cases with few or weak support teeth, and in situations of distal extention and in implant-supported dentures.[11]

Resilient design can be modified based on the angle and space between the PC and SC (Fig.2), which is a) Marburg Design. It is known as a resilient design and was first introduced by Lehmann and Gente in 1988. A third of the PC cervix is parallel to the SC and creates space between the crowns (Fig.2a). This space will allow for the occurrence of lateral minor movements of the crown and a smooth, effortless gliding along the axis of the insertion direction. This design offers guidance, support, and stability against dislodging motion but without retention. The marginal part of the periodontium supporting tooth is not covered by the denture base. [3,11] The Marburg design can be easily modified to obtain vertical movement, which when intended for mucosa-supported RPD should be able to accommodate 0.3-0.5 mm of vertical movement. The telescopic denture base will be in contact with the mucosal denture-bearing at the time of insertion, and there will be space between the PC and SC. When the occlusal is loaded, the denture will move vertically; the amount of movement depends on the compressibility (resilient) of the mucosal denture-bearing;[3] b) Hofmann and Ludwig Design. The half-cervical part of the PC is parallel to the SC and the half-occlusal part is conical with the presence of a space of 0.2-0.5 mm between the PC and the SC in the occlusal part (Fig.2b);[11] c) Yalisove design has a space in the cervix where only two-thirds of the occlusal is in contact. On the third of the servix, there is a 0.003-0.010 inch space between the PC and SC (Fig.2c), allowing the SC to rotate when the distal-end mucosa is under load and preventing unwanted friction. There is a difference between the self-supporting telescopic type with dental support using coping with tapers 2-3 and the self-releasing type with mucosal support using taper 16, where there is no retention, but there is support and load distribution along the axis of the support teeth. [9,11]

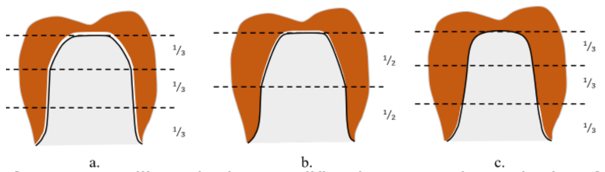

Figure 2 Resilient design modification; **a** Marburg design, **b** Hofmann and Ludwig design, **c** Yalisove design

Manufacture of primary and secondary crowns

The conventional manufacturing process, also referred to as the lost-wax technique in the manunufacture of PC and SC, has shortcomings due to the high casting temperature and oxidation properties of the metal after casting. The high modulus of elasticity of the material makes manual processing and RF adjustment more difficult In the micrometer range, zero tolerance of an undesired press or clearance fit is obtained. [14]

Recently, CAD/CAM systems have attracted great attention as a suitable alternative to the wax loss technique in the manufacturing of metal. Over time, the processing accuracy of CAD/CAM systems has improved greatly thanks to the improvement and development of measuring devices and processing machines. One of the main benefits is that digital technology has the characteristic of producing very precise results up to within the range of the micrometer when the parameters used are correct and can avoid errors related to conventional systems.[13,14] With the development of CAD/CAM technology, new methods in the manufacture of metals and non-metals can be carried out starting from the wax-up process to obtain precise and accurate results. The internal and marginal fit of the milled crown, which might take the shape of an angle taper and the space between the PC and SC, is either superior or equal to that of the cast crown.[15-18]

Primary and secondary crown materials

In dentistry, especially in prosthetic dentistry, metal alloys are the most common material due to their excellent physico-mechanical properties, with precious and non-precious metals. Precious metal is the first choice in making TC, but due to economic reasons, non-precious metal has also been used.[1,15–18] The material originally used for the manufacture of PC and SC is high-gold alloy due to the relatively low modulus of elasticity compared to other metals that allow conventional manufacturing through casting technology and uncomplicated adjustments chairside. Since the price of gold has increased significantly over the past few decades, numerous other materials can be employed with various TC designs. [14]

The TC and metal-free dental prosthetics have both become popular in recent years. The use of ceramic materials in the manufacture of telescopic dentures began in 2000 and has a high demand not only among dentists but also among patients. Zirconia and PEEK materials are biocompatible materials with good mechanical properties and excellent aesthetics.[1,15–18]

PEEK is a polymeric material with high thermomoplastic polymer density properties with a semicrystalline aromatic linear structure that has good physical and chemical properties such as toughness, hardness and elasticity, and a low molecular weight in the absence of metal that provides biocompatible denture material. [17]

Zirconia, also known as ZrO2, is a ceramic material with high biocompatibility that exhibits outstanding bending and tensile strength, extremely high compact resistance, and self-repairing capabilities that stop fracture propagation. There are various forms of zirconia used in dentistry, including Yttria full stabilized tetragonal zirconia polycrystal, zirconia toughened alumina, and magnesium partially stabilized zirconia (Mg-PSZ) (3Y-TZP).[15,17]

DISCUSSION

Telescopic dentures with cilindrical and conical crown designs provide a rigid support on the support teeth. If the load given is large and only on a few support tooth, it can cause teeth mobility and premature tooth loss.[3] According to Sahin et al., a rigid-design telescopic denture produces a larger strain on the support teeth than a resilient one.[2] Therefore, it can be said that cilindrical, conical, and resilient crown designs can be used on RPDs supported by the tooth- or tooth-mucosa-support, but only resilient crown designs can be used on RPDs supported by the mucosa support since only these designs can offer the PC and SC with vertical movement. This is due to the fact that the cilindrical and conical crown designs, which induce friction and wedging effects, are unable to tolerate RPD movement in either the occlusogingival direction under load or the opposite way when the load is removed.[3]

A number of variables, including PC thickness, PC height, taper angle, SC adaptability, and space width in the occlusal section of the PC and SC, might affect the retentive force in the telescopic crown.[13] Retentive force in the TC occurs in the entire removal process where the conical crown can be removed forcelessly shortly after the initial force. Different types of retention will have an impact on how the TC surface wears when in contact. Friction and keying will result in wear due to abrasion, adhesion, and consecutive surface spalling.[8] When the load given is large, the SC goes deeper due to the increase in strain and RF.[6]

The retentive force on the conical crown has a significant effect when the taper angle and the height of the support teeth are modified due to the wedging effect where the taper angle on the PC provides a wider resistance surface. In order to increase the RF, the wedge effect deepens and the taper angle decreases. As a result, the taper angle may affect RF management. Therefore, the taper angle can be a factor controlling the RF. Clinically, RF ranges 5-9 N per supported tooth. The RF difference that occurs due to the taper angle can be related to the coefficient of static friction of the material. The smaller the taper angle, the smaller the static friction coefficient. When the SC sits on the PC and the load is applied to the occlusal surface, the side surface of the SC will undergo a slight deformation due to the wedge effect that will produce RF.[6,8,13,19] Gungur et al reported that RF TC in-

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creased as the taper reduced. This is also the same as Nakagawa's research, which stated that there was a significant difference between RF and PC angle tapers when given different forces regardless of the space between the PC and the SC.[19]

It is crucial to note that the conical crown's retention mechanism varies from that of the cylindrical crown. Deformation from the SC is therefore prevented if there isn't space on the occlusal surface between the PC and the SC, which means that the RF won't happen. Therefore, the angle and space taper between the PC and SC can be used as one of the factors in regulating RF.[6,8,13] In the absence of space, the PC and SC will have tight contact and when the load is given, there can be no deformity in the SC and this can damage the RF, which can be said to be sheared or sliding between the PC and SC. Shimakura et al. tested specimens with 0, 50, and 100 µm occlusal space and found that there were significant RF differences in spaces of 0 and 50 µm, but there were no significant RF differences in spaces of 50 and 100 µm.[13] Schwindling found the resulting RF in accordance with the force required in the abutment teeth when there was an occlusal space of 50 µm. However, in another study that looked at the space of 0, 10 and 20 µm between PC and SC, there were no significant RF differences.[6,19] Nakagawa also stated that the space setting does not show a significant difference, but if there is no space on the occlusal surface on PC and SC during insertion, there will be no RF due to the wedge effect. The increase in load will increase RF but is not affected by the space.[19]

Shimakura looked at RF at telescopic dentures with heights of 4 and 6 mm; taper angle of 6; space between 0.50 and 100 µm; knife edge margin. The results of his research showed that TC with a height of 4 mm; space 0 µm; load of 50 N, found RF of 6.3 N. Along with the addition of space in the occlusal region and the increased load, the RF is also increasing. When the height is 4 mm with a space of 100 µm, the maximum RF reaches 17.4 N. At a height of 6 mm with a space of 0 µm, a RF of 7.8 N is found; and in a space of 100 µm a maximum RF of 35.6 N is found.[13]

A large load, a small angle taper, a thin SC, and a wide shoulder on the PC cervix will result in a large RF. This is evidenced in the research of Nakagawa et al which states that the taper angle on the conus crown shows the greatest contribution (74.5%) followed by the load received (11.62%); errors in load, PC space and SC, SC thickness and shape of the PC cervical border.[6]

One of the most frequent technical failures is retention loss, which depends on the principle of a retention mechanism.[1] According to Arnold et al, the combination of materials and manufacturing techques used affects the RF on TC. The properties of the material used to create the double crown are crucial.[1,14] In the CAD/CAM manufacturing process, milled non-precious metal TC showed the highest RF and also during wear simulation. This is because the results of CAD/CAM have a uniform surface, not too rough, with a consistent distance between PC and SC. In the conventional manufacturing process, a lower RF value was found with a significant RF loss. This is due to the fact that the TC surface is inhomogeneous with a thickness that varies between PC and SC and has irregular surface contacts. The retention or friction of the results of the fabarication of the TC conventional is ensured through recurring elevation and punctual contacts.[14] When making TC by the lost-wax method, the technician needs to pay attention to the water-powder ratio of the investment material and control the expansion of the casting mold to obtain the appropriate space between the PC and SC. Therefore, it requires the ability, experience, and accuracy of dental laboratory technicians in making TC. [8,13]

Research according to Wagner et al, telescopic denture with PEEK material made with CAD/CAM system shows stable retention load value and according to Joao Paolo et al also stated that PEEK provides low-stress concentration due to low elastic modulus properties and good strength.[20] The higher the elastic modulus of the PC material, the higher the stress magnitude in the structure, but analysis of the periodontal ligaments and bones of the model showed that the PC material did not affect strain outcomes. [20]

When using non-precious metal materials that have a smaller modulus of flexibility, it can cause strains to increase and provide a hazardous effect. Where strains are effective in the distribution of loads on bone, pulp, periodontal ligaments and metal structures. Strain and tensile stress will also increase as the height and angle of the telescopic crown increase.[5] Arnold concluded that TC with different designs and different materials will produce different RF and long-term retentive behaviors as well. This is because the telescopic crown that has a lot of surface contact between the PC and SC can cause RF to be easily lost.[14]

Stock et al looks at RF on different PEEK materials with different tapers. Milled PEEK with taper 0 shows the lowest RF, whereas taper 2 shows the highest RF. Pressed PEEK does not show a sig-

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nificant RF difference with different angles. This is because pressed PEEK is softer so that it is easier to deform in SC so as to reduce RF. Ohkawa et al suggest that the maximum taper is 2 because if it exceeds 2, the retention will disappear quickly.[21] This is in line with the research of Merk who tested RF with zirconia as PC and PEEK (breCom BioHPP blanks milled, BioHPP pellet pressed, and BioHPP granulate pressed) as SC with angles of 0, 1 and 2. It was concluded that the highest RF was at an angle of 0 in the pressed pellet material group (21.4 N). At an angle of 1 milled PEEK had the lowest RF (6.8N), but at angle 2 there was no significant effect.[16] Although angle 1 with PEEK milled material has the lowest retention, the RF value is in the ideal RF range.

Nakagawa tested RF with Ce-TZP/A zirconia material with CAD/CAM as PC and SC with angles of 2, 4 and 6; and spaces of 0 and 100 µm. The average RF at angle 2 is 23 N, angle 4 is 8 N and there is no RF at angle 0. Good RF shows up on taper 4 with a load of 50 N.[19] Although at angle 2 it is the best RF, it has passed the ideal RF value, so it is feared that it will affect the periodontal health of the support teeth. This is in contrast to Nakagawa's research comparing the bright-stabilized material zirconia/alumina nanocomposite with CAD/CAM system, which found RF at angles 2, 4 and 6 is 35.8 N, 15.9 N and 1.4 N.[6] Where at angles 2 and 4 it has exceeded the recommended RF but angle 6 is below the optimal value of RF.[6]

It is concluded that telescopic crowns are classified based on the taper angle and space between the PC and SC into cylindrical, conical, and resilient designs. Cylindrical crowns and conus crowns are rigid designs, where cylindrical crowns have a parallel surface (0°) so as to get retention through frictional forces, while conus crowns get retention through wedging effect and have angles that vary 2-6 without any space between PC and SC. A resilient crown is also referred to as a non-rigid design, where there is no retention through frictional force or wedging effect and has a taper angle similar to the conus crown but has a space between the PC and SC which ranges 0-100 µm. This space allows the movement of the denture to the mucosa caused by the occlusal functional load so that it can compensate for the difference in mucosal compresibility.

Cylindrical TC designs are rarely used because it is difficult to get precise contact between the PC and SC, thus conus designs or resilient modifications are more recommended. Resilient crowns were modified into Marburg design, Hofmann and Ludwig design, and Yalisove design. This design is a modification of the combination of conus crown and/or cylindrical crown with the presence of space on several parts or the entire surface of PC and SC. The smaller the taper angle, the larger the RF, but this depends on the material used. While the space between PC and SC, which is less than 50 µm can affect RF, but without space on the occlusal surface between PC and SC, RF on a PC that has a taper angle will not occur. Therefore, the angle and space taper between the PC and SC can be used as one of the factors in regulating RF. This needs to be considered because the condition of the support teeth is not the same in every TD case, so that the RF produced on the support teeth can affect the periodontal health of the teeth.

It is suggested further research on the load distribution of telescope dentures based on resilient modified designs (Marburg, Hofmann, and Yalisove designs) still needs to be developed because the resilient design modification has a taper angle and space with different sizes and locations.

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