PERIODONTICS REVISITED

Shalu Bathla

JAYPEE

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SG Damle
Thomas E Van Dyke

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CHAPTER

2 Periodontal Ligament

Shalu Bathla

INTRODUCTION

The attachment apparatus of the tooth includes the periodontal ligament, cementum and alveolar bone. *Periodontal ligament is the soft, specialized connective tissue situated between the cementum covering the root of the tooth and bone forming the socket wall.* Its width ranges from 0.15 to 0.38 mm. Periodontal ligament's shape is like an hourglass apicocoronally, corresponding to the rotation point of the tooth. Periodontal ligament is thinnest at the axis of rotation in the middle and widens coronally and apically. The synonyms of periodontal ligament are periodontal membrane, alveolodental ligament, desmodont, pericementum, dental periosteum and gomphosis.

DEVELOPMENT

As the crown approaches the oral mucosa during tooth eruption, the fibroblasts of dental follicle become active and start producing collagen fibrils. These fibers initially lack orientation, but they soon acquire an orientation oblique to the tooth. The first collagen bundles appear in the region immediately apical to the cementoenamel junction and give rise to the gingivodental fiber groups. As tooth eruption progresses, additional oblique fibers appear and become attached to the newly formed cementum and bone. The transseptal and alveolar crest fibers develop when the tooth merges into the oral cavity. Alveolar bone deposition occurs simultaneously with periodontal ligament organization **(Fig. 2.1).** During eruption, cemental Sharpey's fibers appear first, followed by Sharpey's fibers emerging from bone. Sharpey's fibers of bone are fewer in number and more widely spaced than those emerging from the cementum. At a later stage, alveolar fibers extend into the middle zone to join the lengthening cemental fibers and attain their classic orientation, thickness and strength when occlusal function is established.

CONSTITUENTS

A. Periodontal ligament fibers
B. Cellular elements
C. Ground substances
   i. Glycosaminoglycans
   ii. Glycoproteins

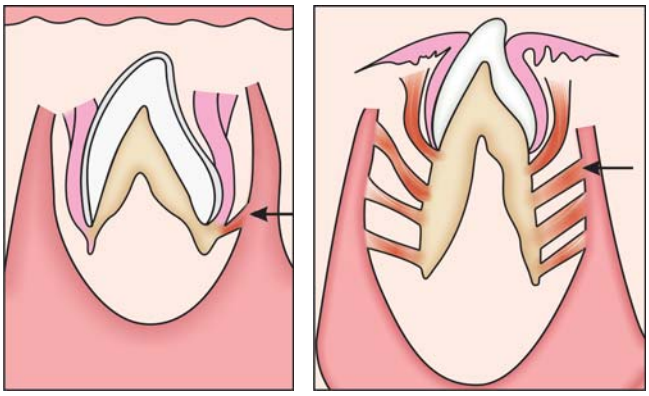

Fig. 2.1: Development of principal periodontal ligament fibers

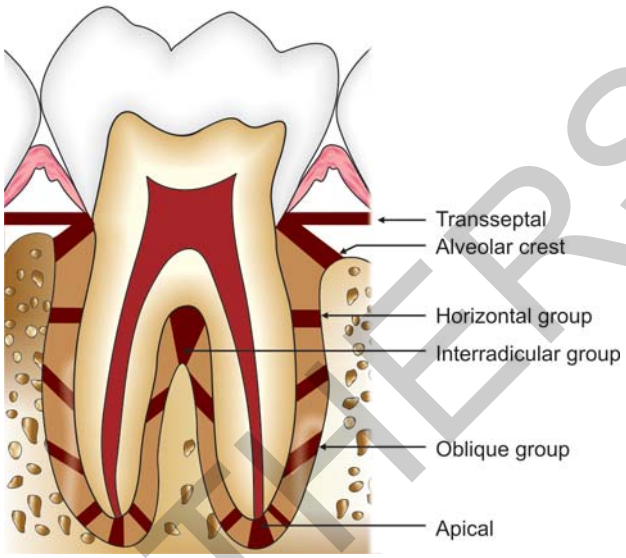

Fig. 2.2: Principal periodontal ligament fiber groups

Periodontal Ligament Fibers

Fibers in human periodontal ligament are made up of collagen and oxytalan. Elastic fibers are present only in the wall of blood vessels. Oxytalan are immature elastic fiber. The orientation of these fibers are different from collagen fibers been in axial direction instead of collagen fibers running from bone to tooth. The one end of these fibers is embedded in cementum or bone and the other end in the wall of blood vessel. Thus, they support the blood vessels of periodontal ligament. These are numerous and dense in cervical region of the ligament.

Collagen: There are at least 19 recognized collagen types encoded by 30 separate genes, dispersed among at least 12 chromosomes. Three polypeptide alpha chains coil around each other to form typical triple helix configuration. It is a protein composed of different amino acids, the most important being glycine, proline, hydroxylysine and hydroxyproline. It always contains hydroxylysine and hydroxyproline. Types I, III,V, VI, XII (FACIT) of collagen are present in periodontal ligament. Collagen is synthesized by fibroblasts, chondroblasts, osteoblasts, odontoblasts and other cells. It is secreted in an inactive form called as procollagen, which is then converted into tropocollagen. In the extracellular space, tropocollagen is polymerized into collagen fibrils which are then aggregated into collagen bundles by the formation of crosslinkages. There is rapid turnover rate of periodontal ligament collagen, with half life of only 10 – 15 days, which is about 5 times faster than gingival collagen.

The principal fibers of periodontal ligament are arranged in six groups **(Fig. 2.2)** and are named according to their location and direction of attachment:

1. *Transseptal group*: Extends interproximally over alveolar bone crest and are embedded in the cementum of adjacent teeth. They are reconstructed even after destruction of the alveolar bone has occurred in the periodontal disease and are responsible for returning teeth to their original state after orthodontic therapy.
2. *Alveolar crest group*: Extends obliquely from the cementum just beneath the junctional epithelium to the alveolar crest. They prevent extrusion and lateral tooth movements.
3. *Horizontal group*: Extends at right angles to the long axis of the tooth from cementum to alveolar bone. This fiber group resists horizontal pressure against the crown of the tooth.

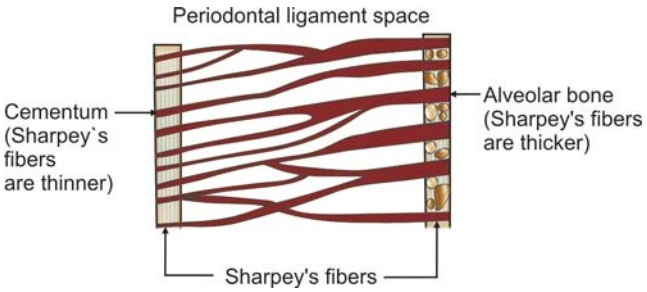

Fig. 2.3: Sharpey's fibers

4. *Oblique group*: Extends from the cementum in a coronal direction obliquely to the bone. They bear vertical masticatory stresses and transform vertical stress into tension on the alveolar bone.
5. *Apical group*: The apical fibers radiates in irregular fashion from cementum to bone at apical region of socket. They prevent tooth tipping, resist luxation and protect neurovascular supply to the tooth.
6. *Interradicular group*: These are found only between roots of multirooted teeth running from cementum into bone, forming crest of interradicular septum. They prevent luxation, tooth tipping and torquing.

The ends of the periodontal fibers that are embedded in alveolar bone and cementum are called Sharpey's fibers. On the cementum side these Sharpey's fibers are much thinner in diameter and insert at closer intervals as compared with the alveolar bone side **(Fig. 2.3)**. These differences in the pattern of insertion have clinical importance in the distribution of forces that are generated within the periodontal ligament during occlusion, traumatic forces and tooth movement. These forces are more evenly distributed along the cementum surface and are more concentrated along the more widely spaced insertions on the alveolar bone side. As a result, in response to mechanical forces, there is generally a remodeling of the periodontal housing on the alveolar bone side and not on the cementum side, preventing the possibility of significant cementum and root resorption.

Cellular Elements

1. Connective tissue cells:
   a. Synthetic cells
      - *Fibroblasts*: These are the most predominant connective tissue cells. Fibroblast are a spindle shaped or stellate cells with an oval-shaped nucleus containing one or more nucleoli. They originate from mesenchymal cells. Fibroblasts have the ability to synthesize and secrete a wide range of extracellular molecules like collagen fibers, elastic fibers, proteoglycans, glycoproteins, growth factors and enzymes (collagenase). These cells are capable of both synthesizing and degrading collagen.
      - *Cementoblasts*: These are the cells responsible for secreting the organic matrix of cementum within the periodontal ligament.
      - *Osteoblasts*: These are found on the surface of the alveolar bone. Their gross appearance and ultrastructure is similar to that of osteoblasts found elsewhere in the body.

   b. Resorptive cells
      - *Osteoclasts*: These are bone resorbing cells which are formed by fusion of mononuclear cells arising from bone marrow.
      - *Fibroblasts*: These cells are also responsible for degrading collagen fibers.
      - *Cementoclasts*: These are mononuclear cells resembling osteoclast located in howships lacunae.
2. Epithelial cells: These are remnants of Hertwig's root sheath which are present close to cementum throughout the periodontal ligament and more in apical and cervical areas. When stimulated they proliferate and participate in the formation of periapical cysts and lateral root cysts. It has been proposed that epithelial cell rests of Malassez play an important role in the maintenance of periodontal ligament space. In physiologic conditions, it is therefore thought that these cells, that are devoid of any mineralization propensity, may contribute to maintain a non – mineralized area. These cells are involved in pathogenesis of several disorders including pocket formation. The presence of c – met receptors in the epithelial cell rests of Malassez suggest that these cells can respond to the inflammatory cytokine, Hepatocyte growth factor. This scatter factor is thought to be capable of aiding migration of these cells and hence aid in the pathogenesis of pocket. These cells are also thought to be responsible for cementum repair as they are found in areas of resorption when mechanical injury was created in experimental animals. It has been suggested that cells retain the capacity to differentiate into cementoblasts and lay down matrix. Thus, epithelial cell rests of Malassez are thought to play a role in physiological maintenance of periodontal ligament space; may play a role in pathogenesis of

pocket formation and probably may mediate process involved in regeneration.
3. Immune system cells: Various defense cells present in periodontal ligament are neutrophils, lymphocytes, macrophages, mast cell and eosinophils
4. Cells associated with neurovascular elements
5. Progenitor cells

Ground Substance

It is an amorphous, nonfibrous and noncellular matrix which forms the major constituent of the periodontal ligament. Ground substance helps in the transportation of water, electrolytes, nutrients and metabolites to and from the connective tissue cells, thus is essential for the maintenance of the normal function of connective tissue. It is thought to have a significant effect on the tooth's ability to withstand stress loads.

The main constituents are protein-carbohydrate macromolecules. These complexes are divided into proteoglycans and glycoproteins. Proteoglycans are the large group of extracellular macromolecules that consist of protein core to which are attached glycosaminoglycan chains. The proteoglycans that are involved in the organization and regulation of collagen fibers are decorin and biglycan abundantly present in the periodontal ligament. Decorin, especially is present bound to collagen and is important to regulate fibrillogenesis. Decorin is also bound to Transforming Growth Factor-β (TGF-β) and prevents excessive fibrosis and thus prevents excessive cross-linking of the collagen fibers of the periodontal ligament. Glycoproteins are the macromolecules with carbohydrate core. Glycoproteins have adhesive properties which bind cells to extracellular elements.These glycoproteins are grouped into two fibronectin and tenascin. Fibronectin is a large protein which binds cells to collagen and proteoglycans. It promotes the adhesion of fibroblasts to the extracellular matrix and plays a role in the alignment of collagen fibers.

Cementicles are globular masses of cementum arranged in concentric lamellae that lie free in the periodontal ligament or adhere to the root surface. These cementicles may develop from calcified epithelial rests or from calcified Sharpey's fiber or from calcified thrombosed vessels within periodontal ligament.

FUNCTIONS

Periodontal ligament serves the following functions:
1. Supportive:
   - Attaches the teeth to the bone.
   - It maintains gingival tissues in their proper relationship to the teeth.
   - Periodontal ligament protects the blood vessels and nerves from injury by mechanical forces.
   - Periodontal ligament transmits occlusal forces to the bone.
   - It resists the impact of occlusal forces and thus acts as a shock absorber.

Resistance to the impact of occlusal forces:

There are different theories to explain the mechanism of tooth support:

Tensional theory: According to this theory, the principal fibers of periodontal fibers play the major role in supporting the tooth and transmitting forces to the bone. When the force is applied to the crown, principal fibers unfold and straighten, transmitting the forces to alveolar bone, which leads to elastic deformation of the bony socket and then alveolar bone transmits the load to the basal bone.

Viscoelastic system theory: According to this theory, the displacement of the tooth is largerly controlled by fluid movement and fibers play a secondary role. When the forces are transmitted to the tooth, the extracelluar fluid passes from the periodontal ligament into marrow spaces of bone through foramina. Periodontal fiber bundles absorb the slack and tighten, after the depletion of tissue fluids. This leads to blood vessel stenosis. Arterial back pressure cause ballooning of the vessels. The tissue fluid replenishes as the blood ultrafiltrates pass into the tissues.

Thixotropic theory: According to this theory, periodontal ligament has the rheologic behavior of a thixotropic gel (i.e. the property of becoming fluid when shaken/stirred and then becoming semisolid again).

Transmission of occlusal forces to the bone:

The arrangement of the principal fibers is similar to a suspension bridge or hammock. When an axial force is applied to a tooth, a tendency towards displacement of the root into the alveolus occurs. The oblique fibers alter their wavy, untensed pattern; assume their full length; and sustain the major part of the axial force. But when the horizontal or tipping force is applied, two phases of tooth movement occur. One is within the confines of the periodontal ligament, and the other produces a displacement of the facial and lingual bony plates. The tooth rotates about an axis that may change as the force is increased.

2. Sensory: Periodontal ligament is capable of transmitting tactile, pressure and pain sensations by trigeminal pathways.

3. Nutritive: It supplies nutrients to cementum, bone and gingiva through blood vessels and lymphatics.
4. Formative: The tissues have the regenerative capacity in providing the cell lineage namely osteoblast, cementoblast and fibroblast. Thus, it helps in the formation and resorption of cementum and bone during physiologic tooth movement and repair of injuries.
5. Homeostasis: With the presence of both formative and resorptive activity the periodontal ligament provides a homeostasis in the tissue environment.

BLOOD SUPPLY

The blood supply is derived from the inferior and superior alveolar arteries to mandible and maxilla respectively. Blood supply reaches the periodontal ligament from 3 sources:

i. Apical vessels
ii. Penetrating vessels from the alveolar bone
iii. Anastomosing vessels from the gingiva

Blood vessels are present in the interstitial spaces of loose connective tissue between the principal fibers and are connected in the net like plexus that runs longitudinally. These blood vessels are closer to the bone than to cementum. The blood supply increases from the incisors to the molars; is greatest in the gingival third of single rooted teeth, less in the apical third, and least in the middle; is equal in the apical and middle thirds of multirooted teeth; is slightly greater on the mesial and distal surfaces than on the facial and lingual; and is greater on the mesial surfaces of mandibular molars than on the distal. The capillaries of periodontal ligament are fenestrated while in other connective tissues they are continuous. Due to fenestration, they have greater ability of diffusion and filtration which is related to high metabolic requirements of periodontal ligament and its high rate of turnover.

The venous drainage of the periodontal ligament accompanies the arterial supply. Venules receive the blood through the abundant capillary network; there are also, arteriovenous anastomoses that bypass the capillaries. These are more frequent in apical and interradicular regions.

NERVE SUPPLY

The periodontium receives both autonomic and sensory innervations. Autonomic nerves are sympathetic arising from the superior cervical ganglion and terminating in the smooth muscles of the periodontal arterioles. Activation of the sympathetic fibers induces constriction of the vessels. Sensory nerves that supply the periodontium arise from maxillary and mandibular divisions of trigeminal nerve. They are mixed nerves of large and small diameter. They have four types of sensory endings including nocioceptive free nerve endings receptors, two kinds of mechanoreceptors and spindle like receptors. Unmyelinated sensory fibers terminate as nocioceptive free endings. Coiled endings are present mainly in midregion of periodontal ligament. Ruffini endings are low threshold, slowly adapting mechanoreceptors located primarily in the apical areas. They have dendritic ramifications with expanded terminal buttons. Spindle like receptors are for pressure and vibration which are surrounded by a fibrous capsule and located mainly at the apex. About 75% of the mechanoreceptors within the periodontal ligament have their cell bodies in the terminal ganglion while the remaining 25% have their cell bodies in the mesencephalic nucleus.

MAINTENANCE OF THE PERIODONTAL LIGAMENT SPACE

One of the most remarkable features of periodontal ligament is the maintenance of the space in spite of its constant exposure to mechanical forces or orthodontic tooth movement. Following factors have been thought to contribute to this maintenance of periodontal ligament:

1. Periodontal fibroblasts lack osteoblast differentiating genes coding for protein namely bone sialoprotein which is thought to be an initial nucleator of hydroxyapatite crystal. Therefore, *in vitro* formation of crystals does not occur within the periodontal ligament space. Osteocalcin expression within the periodontal fibroblasts under physiological conditions is also less or absent.
2. Inhibitors of mineralization: This is the most important mechanism by which periodontal fibroblasts maintain their space.
   a. *Msx protein*: The greater expression of msx homeobox protein within the periodontal ligament is thought to be a defense mechanism that prevents periodontal mineralization.
   b. *S100 protein*: Periodontal ligament shows a greater expression of S100, a calcium binding protein. Increased expression of S100 seems to regulate expression of osteoblast differentiation genes

coding for proteins such as osteocalcin and alkaline phosphatase and thus, inhibits mineralization.

c. *Periodontal ligament associated protein 1 (PLAP1)*: It is a potent inhibitor of mineralization as it can bind with BMP and antagonize its action. This binding prevents cytodifferentiation and as a result expression of the osteoblast phenotype is restricted.

3. Epithelial cells of Malassez: The presence of epithelial cells of Malassez in the periodontal ligament space is thought to be deterrent to osteoblast differentiation and is, therefore, an important regulator, especially in the coronal areas of the tooth.
4. Nitric oxide (NO): On application of mechanical stress, increased NO production from the periodontal ligament is thought to result in osteoclast activity and bone resorption thereby maintaining the periodontal space.

Characteristic features of periodontal ligament

Hour glass shape
0.15- 0 .38 mm width
Supportive, nutritive, regenerative and sensory functions

POINTS TO PONDER

- ✓ Oblique group is the largest group of periodontal ligament fibers.
- ✓ Intermediate plexus (Sicher 1966): Fibers arising from cementum and bone are joined in mid region of periodontal ligament space giving rise to a zone of distinct appearance in light microscope. It was believed that the intermediate plexus provides a site where rapid remodeling of fibers occurs, allowing adjustment in the ligament to be made to accommodate small movements of tooth. However, evidence derived from electron microscope provide no support for this and was believed to be an artifact.
- ✓ Fibroblasts are described as architect, builder and caretaker of connective tissue and play dual role in collagen synthesis and degradation.
- ✓ Gla proteins are important for the regulation of mineralization in the extracellular matrix. These proteins are called so due to the presence of amino acids that are – carboxylated, called the gla residues. The important members of the gla protein family are Bone gla protein (osteocalcin) and Matrix gla protein (MGP). MGP has been detected in the periodontal ligament and is thought to play a contributory role in the maintenance of the periodontal ligament space.

BIBLIOGRAPHY

1. Bartold PM, Narayanan AS. The Biochemistry and Physiology of the Periodontium. In, Wilson TG, Kornman KS. Fundamentals of Periodontics.Quintessence Publishing Co.1996; 61 – 108.
2. Berkovitz BKB, Schore RC. Cells of the periodontal ligament. In, Berkovitz BKB, Moxham BJ, Newman HN.The Periodontal Ligament in Health and Disease. 2nd ed Mosby – Wolfe 1995; 9 – 33.
3. Bernard GW, Carranza FA. The tooth supporting structures. In, Newman, Takei, Carranza. Clinical Periodontology. 9th ed WB Saunders 2003; 36-57.
4. Freeman E. Periodontium. In, Tencate AR. Oral histology Development, Structure and Function. 5th ed Mosby 1998; 253-88.
5. Holmstrup P. The macroanatomy of the Periodontium. In, Wilson TG, Kornman KS. Fundamentals of Periodontics. Quintessence Publishing Co.1996; 17 – 26.
6. Holmstrup P. The microanatomy of the Periodontium. In, Wilson TG, Kornman KS. Fundamentals of Periodontics. Quintessence Publishing Co.1996; 27 – 46.
7. Linden RWA, Billar BJ, Scott BJJ. The innervations of the periodontal ligament. In, Berkovitz BKB, Moxham BJ, Newman HN. The Periodontal Ligament in Health and Disease. 2nd ed Mosby – Wolfe 1995; 133 – 59.
8. Lindhe J, Karring T, Araujo M. Anatomy of the Periodontium. In, Lindhe J, Karring T, Lang NP. Clinical Periodontology and Implant dentistry. 4th ed Blackwell Munksgaard 2003; 3-49.
9. Melcher AH, McCulloch CAH. Periodontal ligament. In, Bhaskar SN. Orban's Oral histology and Embroylogy. 11th ed Mosby 1991; 203-38.
10. Moxham BJ, Grant DA. Development of the periodontal ligament. In, Berkovitz BKB, Moxham BJ, Newman HN.The Periodontal Ligament in Health and Disease. 2nd ed Mosby – Wolfe 1995; 161 – 81.
11. Nanci A, Bosshardt DD. Structure of Periodontal tissues in health and disease. Periodontol 2000 2006;40: 11-28.
12. Organization of the matrix. In, Arun KV. Molecular biology of periodontium. 1st ed Jaypee brothers 2010; 35-69.
13. Periodontal ligament. In, Grant DA, Stern IB, Listgarten MA. Periodontics. 6th ed CV Mosby Company 1988; 56-75.

MCQs

1. Periodontal fibers which are consistent and reconstructed even after the destruction of the alveolar bone
   A. Apical fibers
   B. Alveolar crest fibers
   C. Oblique fibers
   D. Transseptal fibers

2. Predominant connective tissue cells of periodontal ligament are:
   A. Fibroblasts
   B. Epithelial rests of Malassez
   C. Osteoclasts
   D. Osteoblasts
3. Radiograph of a periodontal ligament of a tooth which has lost its antagonist shows:
   A. Widening of the periodontal ligament space
   B. Narrowing of the periodontal ligament space
   C. Increased density
   D. Sclerotic changes
4. Which of the following amino acid is at every third position of collagen molecule?
   A. Alanine
   B. Glycine
   C. Hydroxylysine
   D. Hydroxyproline
5. The periodontal ligament fibers that mainly prevent the extrusion of teeth are:
   A. Alveolar crest fibers
   B. Transseptal fibers
   C. Horizontal fibers
   D. Inter-radicular fibers
6. The function of fibroblast in periodontal ligament:
   A. Synthesis of collagen
   B. Degradation of collagen
   C. Both A and B
   D. None of the above
7. Which of the following is not correct about periodontal ligament:
   A. It is shaped like hourglass
   B. It is thicker on mesial side of root
   C. It is narrow at axis of rotation
   D. None of the above
8. Largest fiber group in periodontal ligament is:
   A. Transseptal fibers B. Oblique fibers
   C. Horizontal fibers D. Apical fibers
9. The thickness of periodontal ligament is maximum in:
   A. Teeth with heavy function
   B. Teeth with light function
   C. Teeth which are functionless
   D. The third molar teeth
10. The vascular supply of periodontal ligament is:
   A. Greatest in the middle third of the single rooted teeth
   B. In the form of net-like plexus that runs closer to cementum than to alveolar bone
   C. Greatest in the middle third of the multirooted teeth
   D. In the form of net-like plexus that runs closer to alveolar bone than to cementum
11. The following group of fibers is absent in an incompletely formed root:
   A. Alveolar crest group
   B. Oblique group
   C. Horizontal group
   D. Apical group
12. Which of the following fibers regulate the blood flow of periodontal ligament?
   A. Mature elastin fibers
   B. Oxytalan fibers
   C. Eluanin fibers
   D. Collagen Type III

Answers

1. D	2. A	3. B	4. B	5. A
6. C	7. B	8. B	9. A	10. D
11. D	12. B			

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Shalu Bathla, Reader, Department of Periodontology and Oral Implantology, MM College of Dental Sciences and Research, Mullana, Ambala, Haryana, India, was formerly at Yenepoya Dental College, Mangalore, Karnataka, India.

Dr Bathla born in a family of an Air Force pilot, learnt to face hardship since her childhood. The process of molding started from her school days in DAV School, Ambala City, Haryana, India; which she carried forward her education to the DAV Dental College, Yamunanagar headed by Dr SS Dua and further ahead to Government Dental College, Rohtak, Haryana, India under the guidance of Dr (Brig) SC Anand and Dr Sanjay Tiwari.

She has received Gold Medal in Pedodontics and Preventive Dentistry (2001). She has attended various national and international conferences and did various implant courses. She has conducted CDE and has many publications to her credit. She had authored the book *Tips and Tricks in Periodontology*. Now, she is actively involved in undergraduate and postgraduate teaching.

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